SEPTEMBER, 1958

JOURNAL OF THE IRON AND STEEL INSTITUTE

4 GROSVENOR GARDENS · LONDON SWI

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VOL. 190 PART 1

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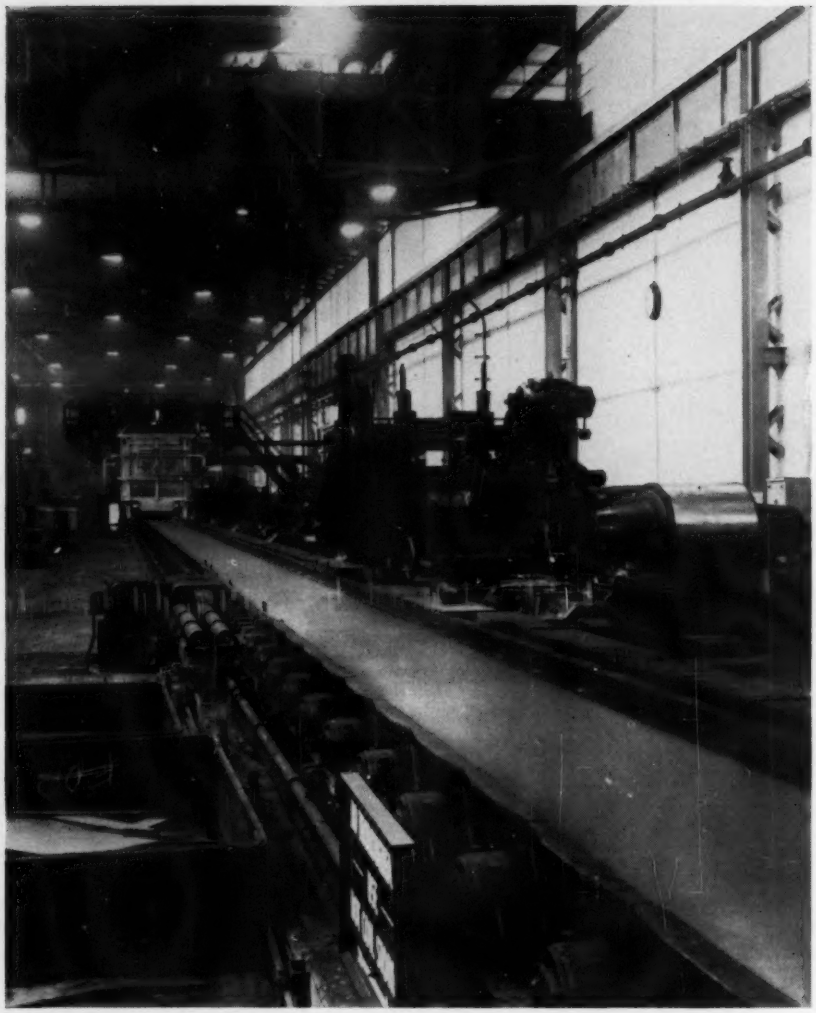
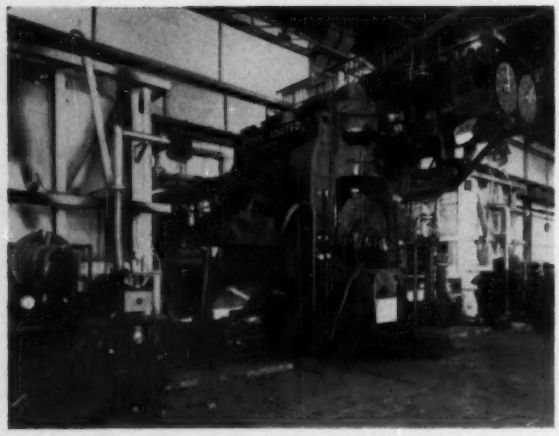
HOT STRIP MILL PLANT

for STAINLESS STEEL with COILING FURNACES





Inaugurated in 1953 on the basis of straight length rolling, the hot mill line at Shepcote Lane Rolling Mills Ltd., Sheffield, is now in production utilizing coiling furnaces, thus becoming the first stainless steel strip plant of this type in Britain.

The original line, embodying Davy-United 35″ × 72″ Reversing Roughing and 27″ and 53″ × 48″ Hot Finishing Mills, was designed with this eventual development in mind. The converted plant, incorporating considerable new Davy-United equipment, is now capable of rolling 8,000 lbs. slabs and producing strip up to 41½″ wide in gauges as low as 0.10″. It offers greater flexibility in operation, increased output and superior quality in the finished product.

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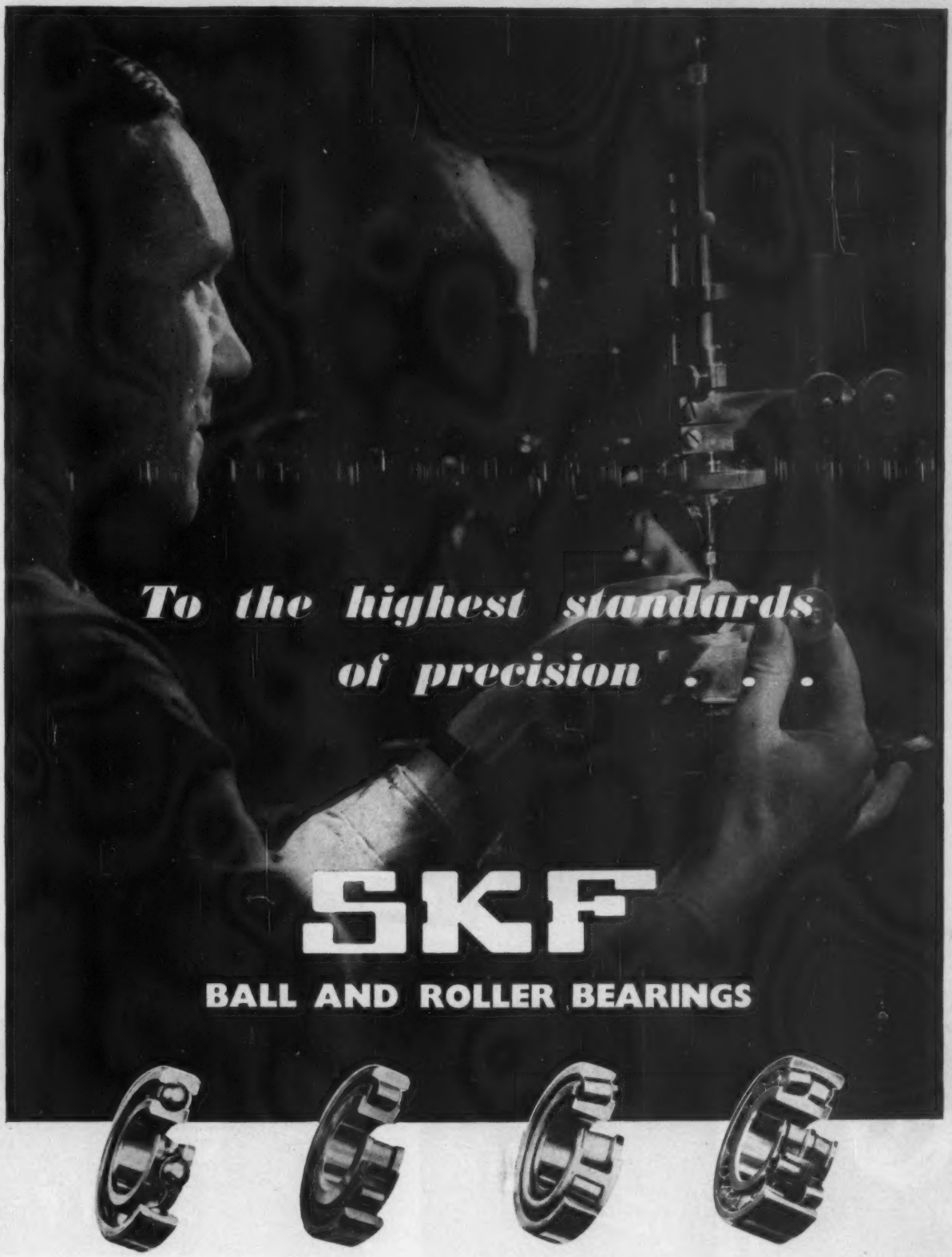

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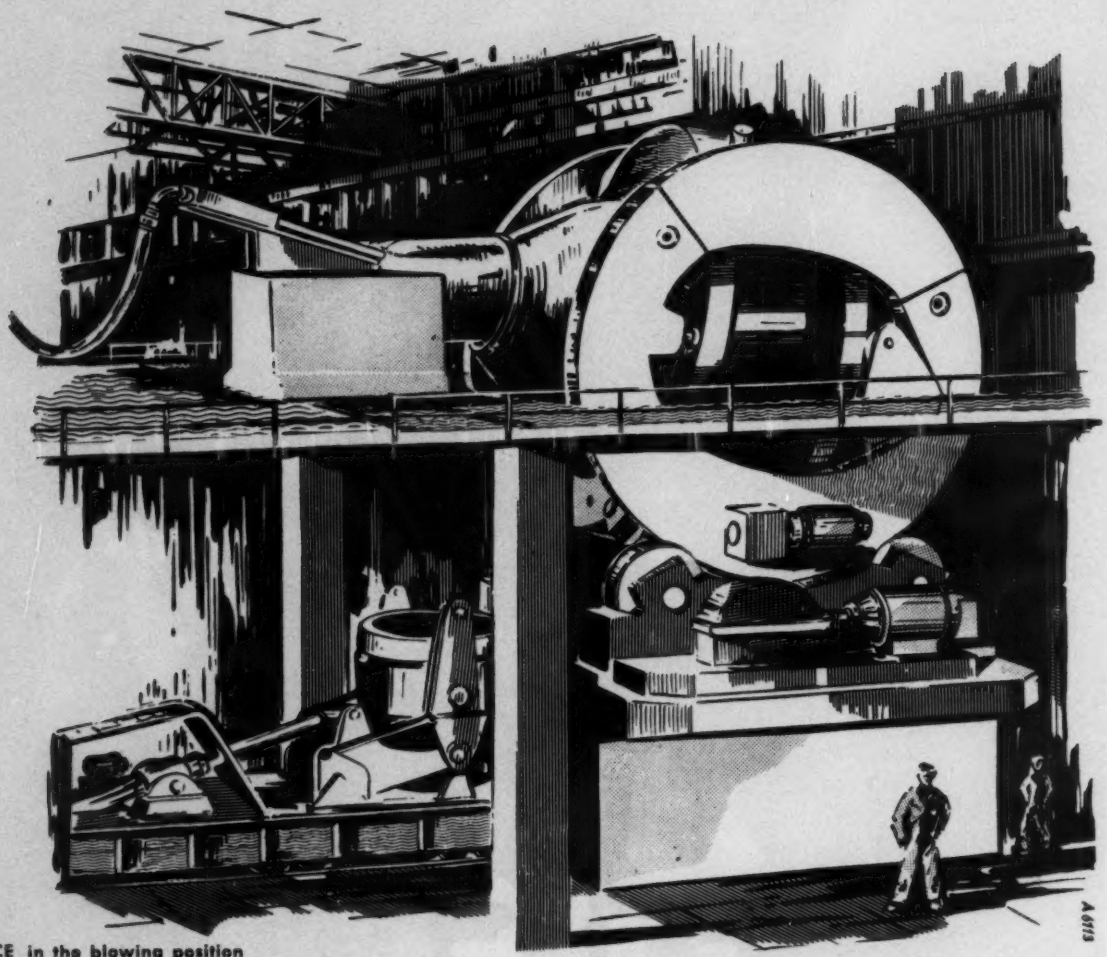
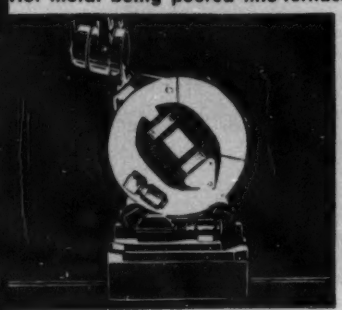
DEMAG

DEMAG is building 100-ton Kaldo furnace plant with exchangeable converter vessels for France.

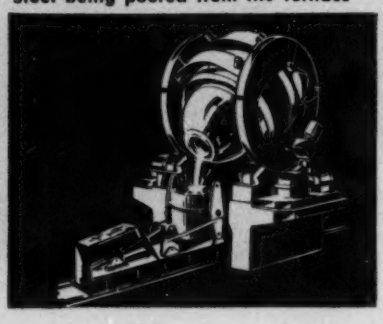


FURNACE in the blowing position

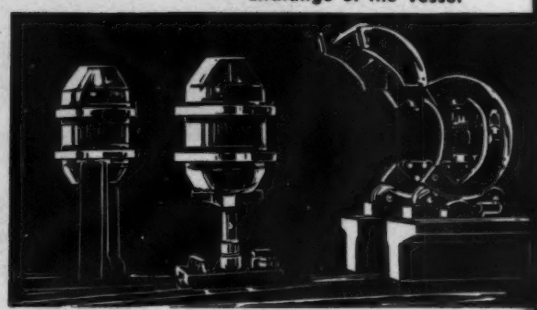
Hot metal being poured into furnace



Steel being poured from the furnace



Exchange of the vessel



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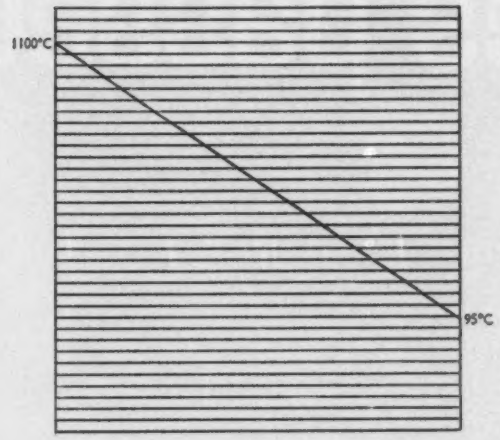
DEMAG AKTIENGESELLSCHAFT DUISBURG GERMANY

Increasing the efficiency of a Furnace with SECOND STAGE INSULATION

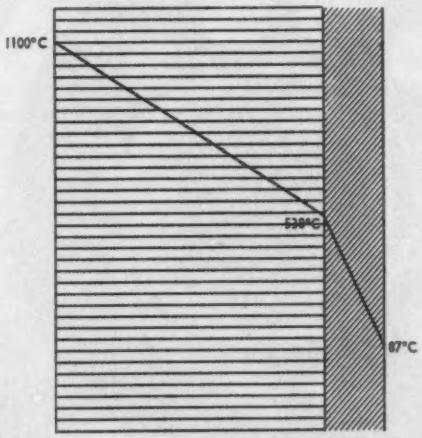
THESE DIAGRAMS TELL THE STORY

A 13½" H.T. BRICK



HEAT LOSS: 289 B.Th.U./Ft²/Hr.
HEAT CONTENT: 14680 B.Th.U./Ft² SUPER.
MASS: 52·9 Lb./Ft² SUPER.

B 9" H.T. BRICK 2" THERBLOC



HEAT LOSS: 243 B.Th.U./Ft²/Hr.
HEAT CONTENT: 13540 B.Th.U./Ft² SUPERFICIAL
MASS: 37·6 Lb./Ft² SUPER.

Diagrams A and B represent alternative methods of insulating a furnace operating at 1100°C. By using the combination of high temperature fire brick and Stillite 'Therbloc' insulation as in diagram B, a thinner, less costly wall loses less heat than A, and if the furnace is used intermittently its low heat capacity brings the further economies associated with speedy heating and cooling.

Therbloc is a lightweight insulating slab manufactured from high grade Stillite mineral wool. Its insulating properties exceed that of Diatomite and Vermiculite. Temperatures range up to 815°C, Fusing temperature 1300°C, Density 14/16 lb./cu. ft., Specific heat 0·19.

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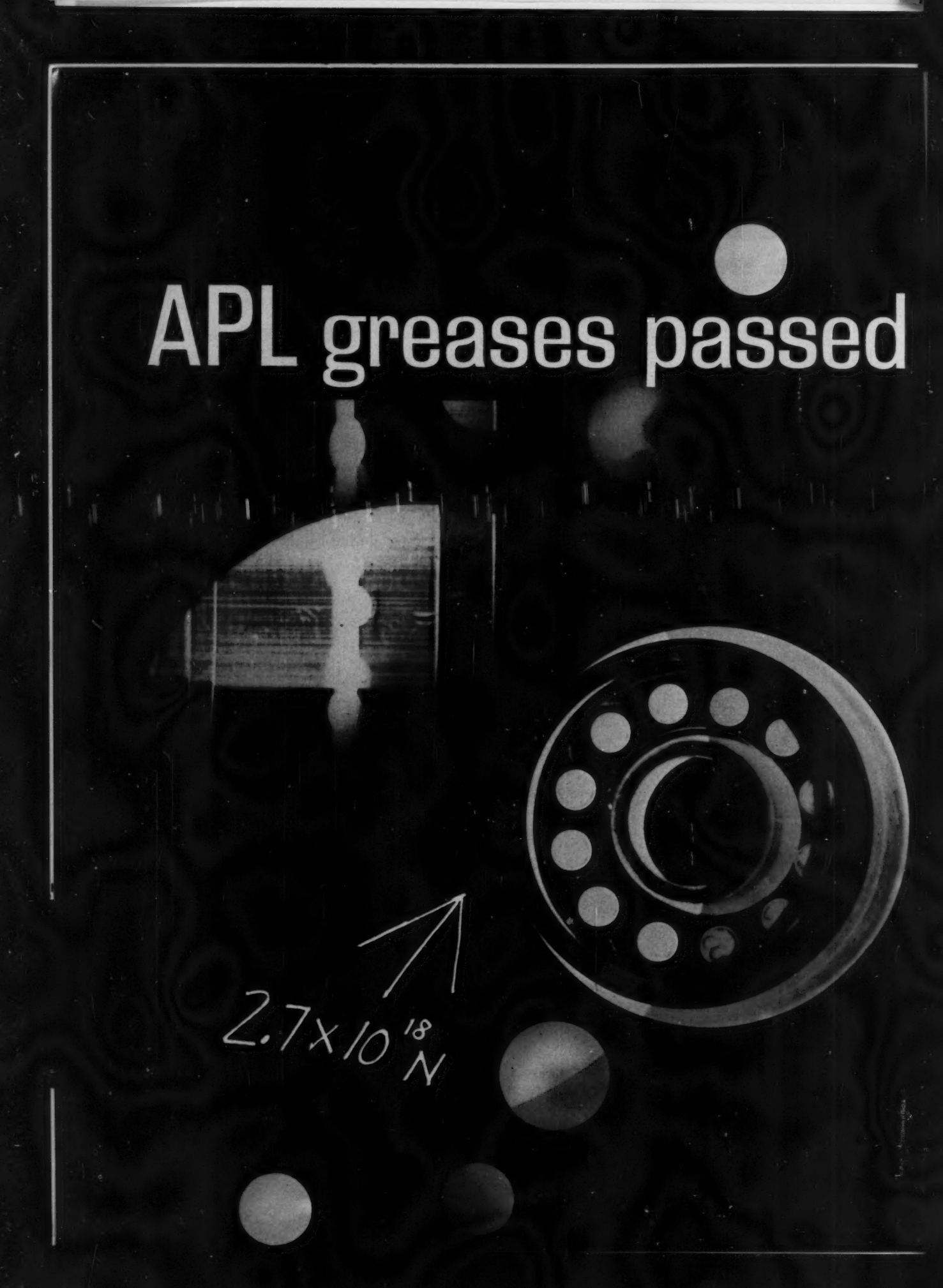
APL greases passed



their finals in June...

Radiation broke up the gel structure of conventional greases. They lost their lubricating properties, turned fluid or granulated. Completely new kinds of greases were needed by the atomic power industry for the bearings situated within the radiation field.

The Shell Group started working out radiation-resistant APL greases whilst most nuclear power stations were still on the drawing-board, and the research that went into them is characteristic of the way Shell set about doing things.

A team of research workers was assembled at Shell's Research Centre at Thornton. After four years of research and testing – both at Thornton and the A.E.R.E. Harwell – APL greases were ready for their finals. A sample was packed into a bearing and sunk into the B.E.P.O. pile. There it was not only subjected to mechanical working and high temperatures in CO_2, but also to an integrated pile dosage of 2.7×10^{18} thermal N. per sq. cm. plus associated radiation. APL greases sailed through their finals – and Shell are proud of it. They should be. For with these greases, Shell completed Britain's first range of Atomic Power Lubricants.

The moral of the APL story is that Shell research is supremely applicational. The Centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right lubricant for the job. If you and your organisation have any major lubrication problem, it will pay you to get in touch with your local distributor of Shell Industrial Lubricants.

The Research Story

Naturally a whole variety of greases were investigated. Conventional metallic soap greases were affected even by relatively low levels of radiation. Other greases based on synthetic and non-petroleum materials were examined and found to be equally unstable. Some of them softened appreciably and became tacky, whilst others hardened.

The Shell APL 700 series of greases are specially processed with an inorganic gelling agent, the base lubricant used being similar to the APL oils previously proved highly resistant to radiation. There were three series of tests. First tests were preliminary radiation tests at Harwell. Then the greases were tested for their lubricating qualities in a high temperature (400°F) pressurised CO_2 anti-friction bearing rig turning at 1,500 r.p.m. For the final tests in June, actual working conditions were simulated at Harwell.

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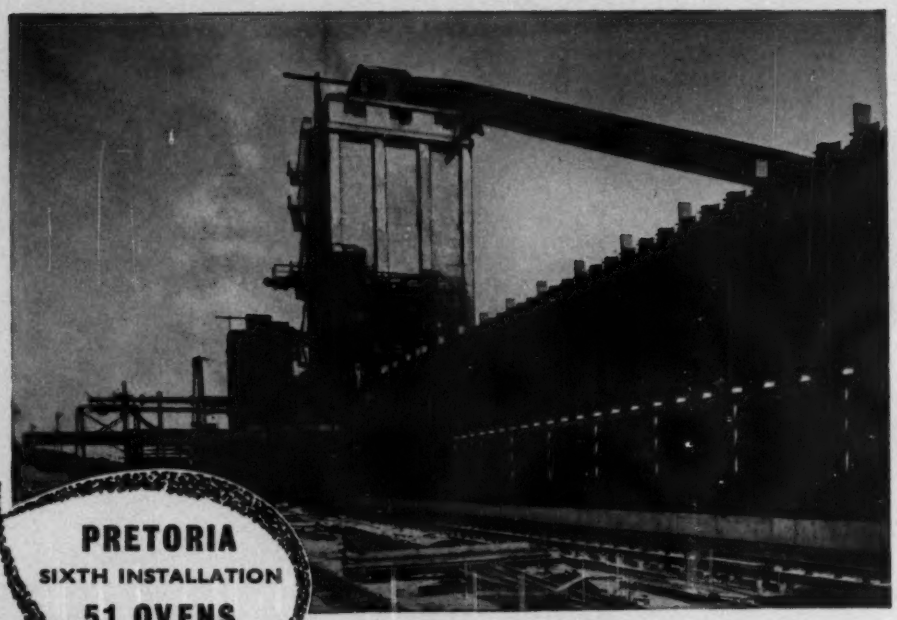
another proof of Shell leadership in lubrication



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51 OVENS

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SECOND INSTALLATION
37 OVENS

MURTON
FIRST INSTALLATION
50 OVENS

CORBY-DEENE
FIRST INSTALLATION
51 OVENS

PRETORIA
FIFTH INSTALLATION
51 OVENS

GLASSHOUGHTON
FIRST INSTALLATION
42 OVENS

REDBOURN
THIRD INSTALLATION
62 OVENS

LYSAGHT
FIFTH INSTALLATION
23 OVENS

VANDERBIJL PARK
THIRD INSTALLATION
55 OVENS

NEW coking plants under construction

The latest installation at the Pretoria Works of the South African Iron and Steel Industrial Corporation Limited is now nearing completion. The installation comprises 51 W-D Becker Coke Ovens, capable of carbonising 1089 tons of coal per day, and is complete with coal and coke handling plants, and by-product recovery and benzole rectification plants. Of the ten new coking plants now under construction this is one of three being built in South Africa.

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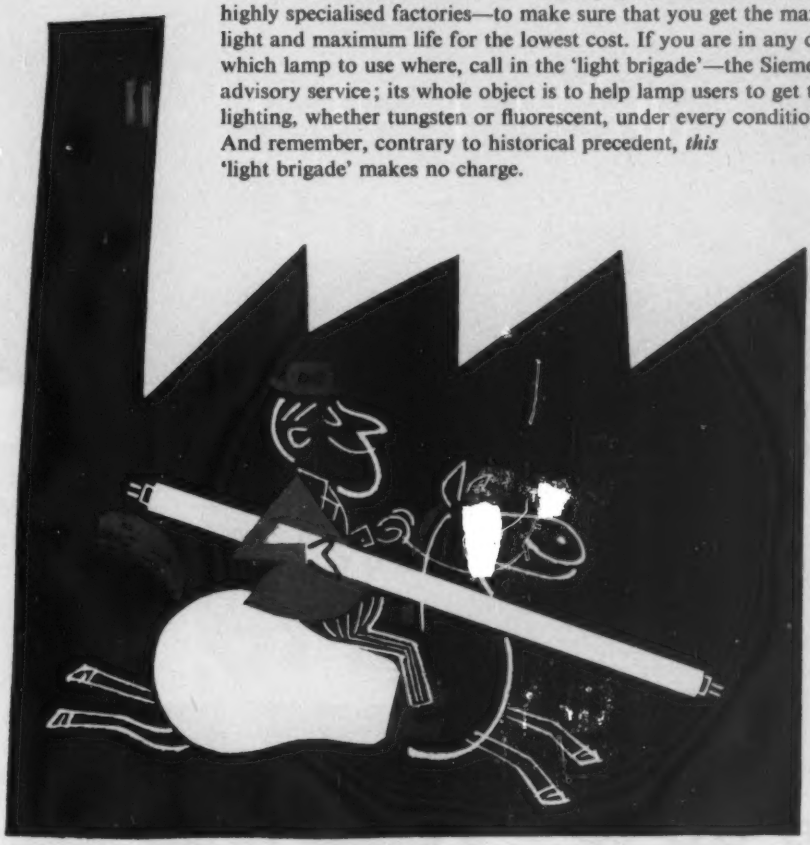

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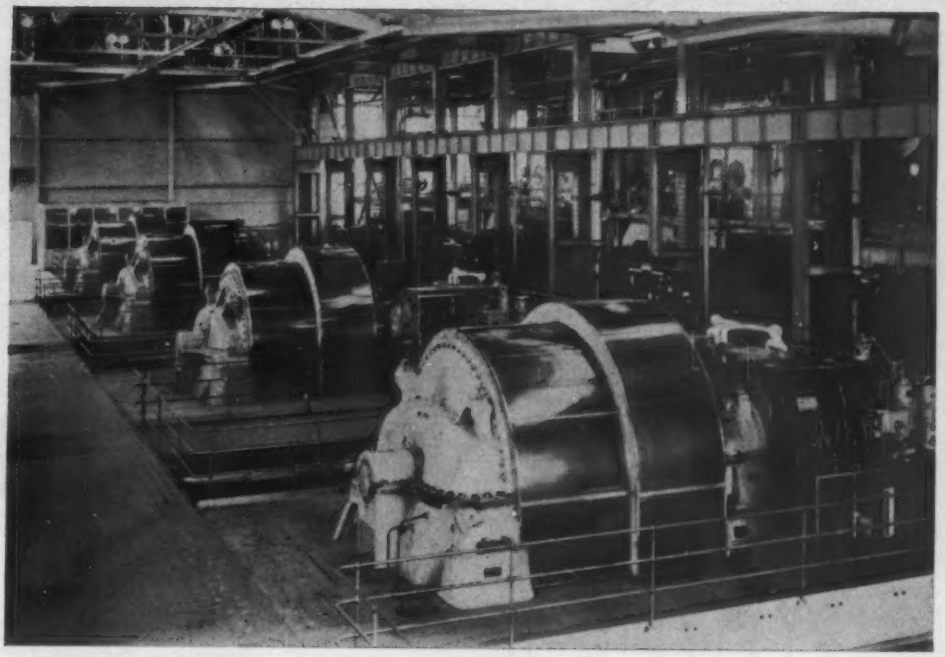
Four Parsons Turbo-Blowers installed in the power house of Consett Iron Co. Ltd., Consett.



Four Parsons Turbo-Blowers installed in the blower house of Appleby-Frodingham Steel Co., Scunthorpe.

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TURBO-BLOWERS FOR BLAST FURNACES

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HIGH-VACUUM FURNACES FOR MELTING, CASTING, ANNEALING, HEAT-TREATMENT AND VACUUM BRAZING AVAILABLE IN ALL CAPACITIES.

(Top) **Vacuum melting Telcon "Mumetal" magnetic materials.**

By courtesy of The Telegraph Construction and Maintenance Co. Ltd.

(Below) **An interior view of induction heater, high temperature, high vacuum sintering or heat-treatment furnace, showing high-frequency coil assembly.**

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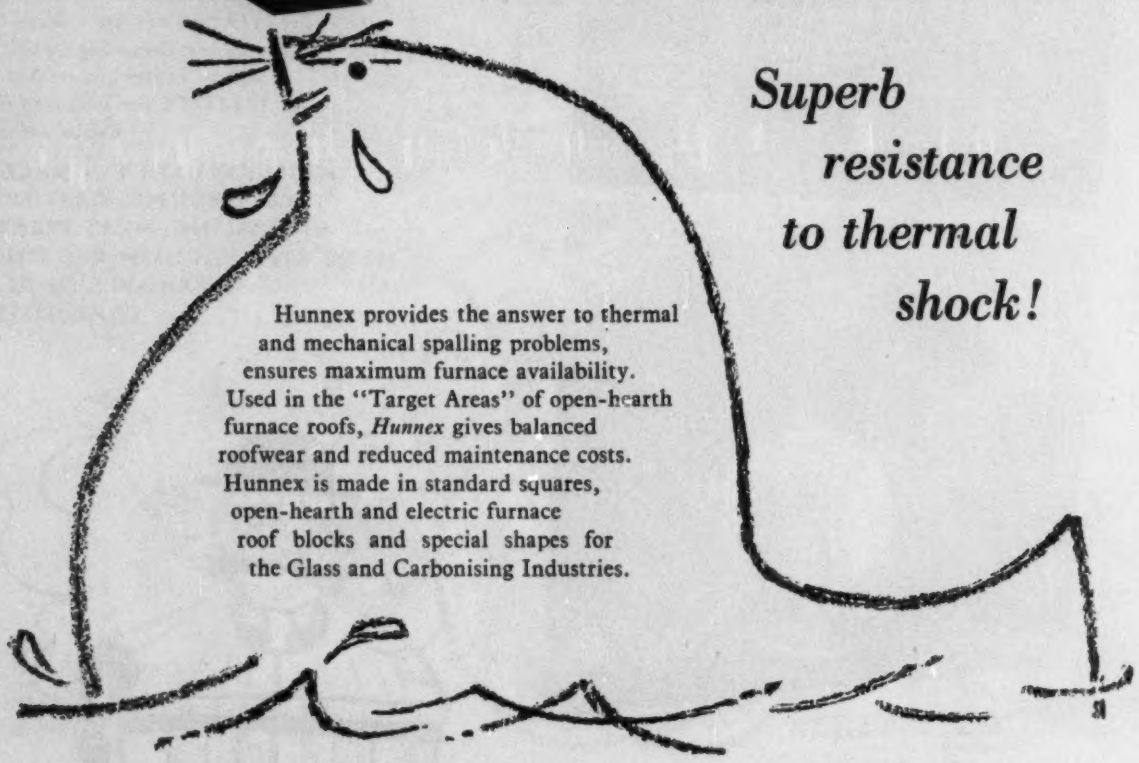

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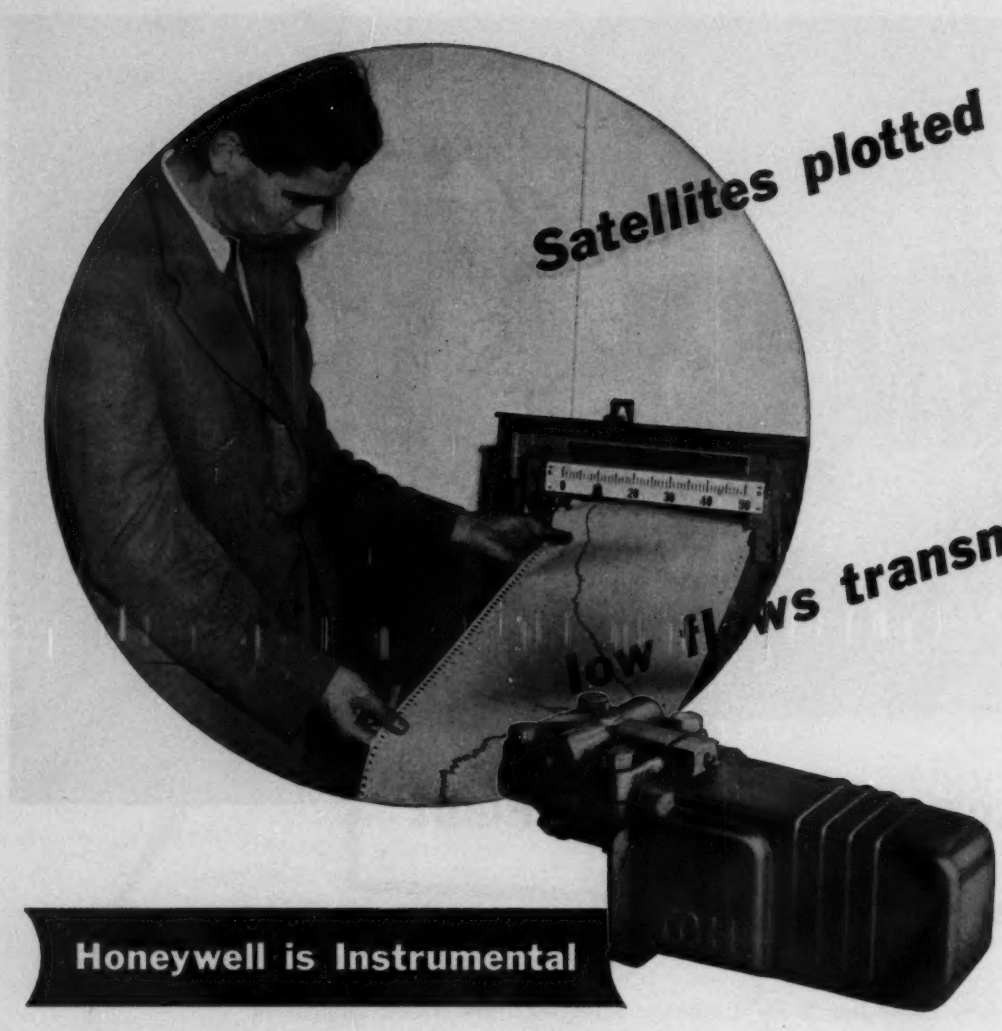

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Specification Sheet 164	ElectroniK Strip Chart Recorders	☐
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FURNACE TOP—

2

3

4

—TO FURNACE BOTTOM

1

Scenes of operations at No. 1 Blast Furnace
(photos by permission of John Summers & Sons Ltd., Shotton)

Furnace blown out	23rd April 1958
Demolition commenced	26th April 1958
Demolition completed	13th May 1958

TOTAL TIME wrecking burden, lining, hearth and bear
18 DAYS
(contract carried out in association with Salem Engineering Co. Ltd.)

1 *'Lumpy going'—half-way down hearth.*
2 *Men removing throat armour.*
3 *Cat Traxcavator commencing digging, Cast House Floor Level.*
4 *The two 'cats' meet—final 'break through'.*

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Hartgusswalzen weiss gehärtet													
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Moiybdän — Hartgusswalzen (M)													
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Cylindres en fonte trempée partiellement													
Teilgehärtete Walzen													
Alloy Clear Chill						■	■						
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Grain Rolls													
Cylindres en fonte à grains													
Feinkörnige Gusswalzen													
Straight													
Cylindres en fonte à grains	■	■											
Halbhartwalzen													
Alloy													
Cylindres en fonte alliée à grains		■	■		■								
Legierte Halbhartwalzen													
Alloy Indefinite Chill Rolls													
Cylindres alliés à trempe indéfinie													
Legierte Indefinite Chill—Walzen				■	■	■	■	■	■	■			
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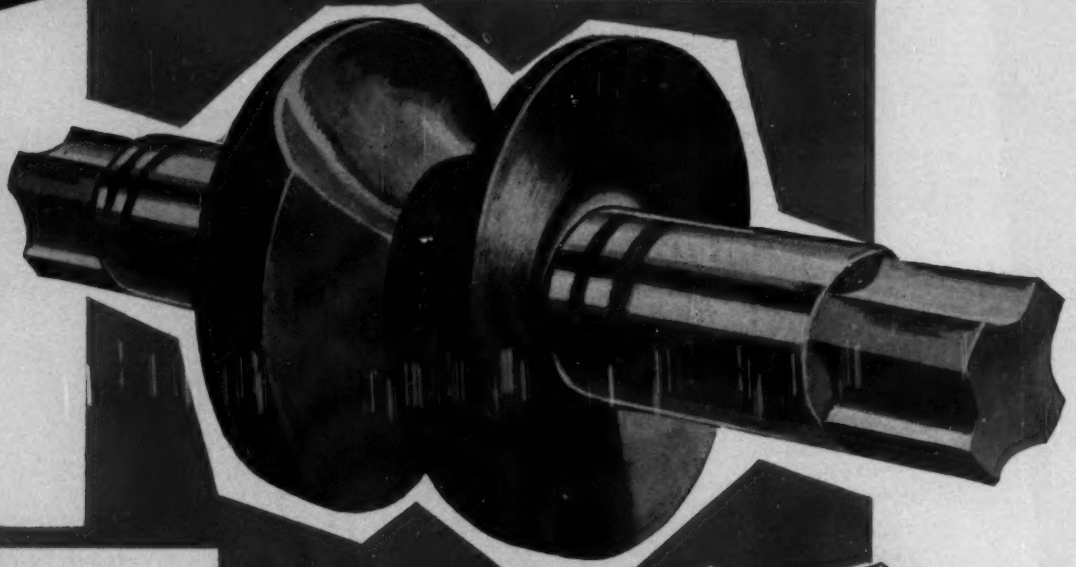
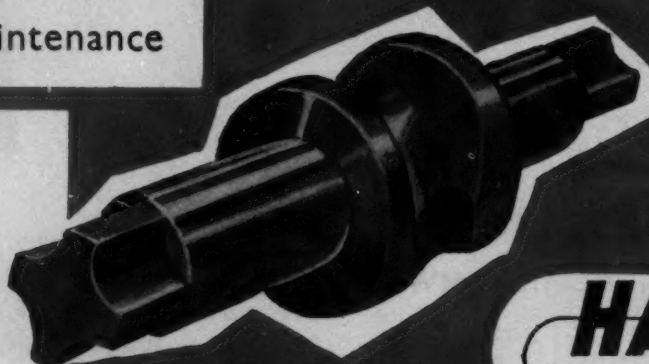


"RESISTA 51"
assures
greater
output
and
reduced
maintenance



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When space is at a premium, Salem One-way Fired Soaking Pits with their patented features are the ideal solution for Ingot Heating. An outstanding feature is the placing of the cover withdrawal-gear below platform level away from the heat—not on top of the cover. These one-way fired pits are designed to take up to 100 tons per charge, for operation on any type of fuel.

The cover withdrawal-gear is normally designed as in the diagram, so that the cover runs up a small slope. It can be supplied, however, so that the cover withdraws on horizontal rails.

Our building and civil engineering division is available for the preparation and erection of foundations.

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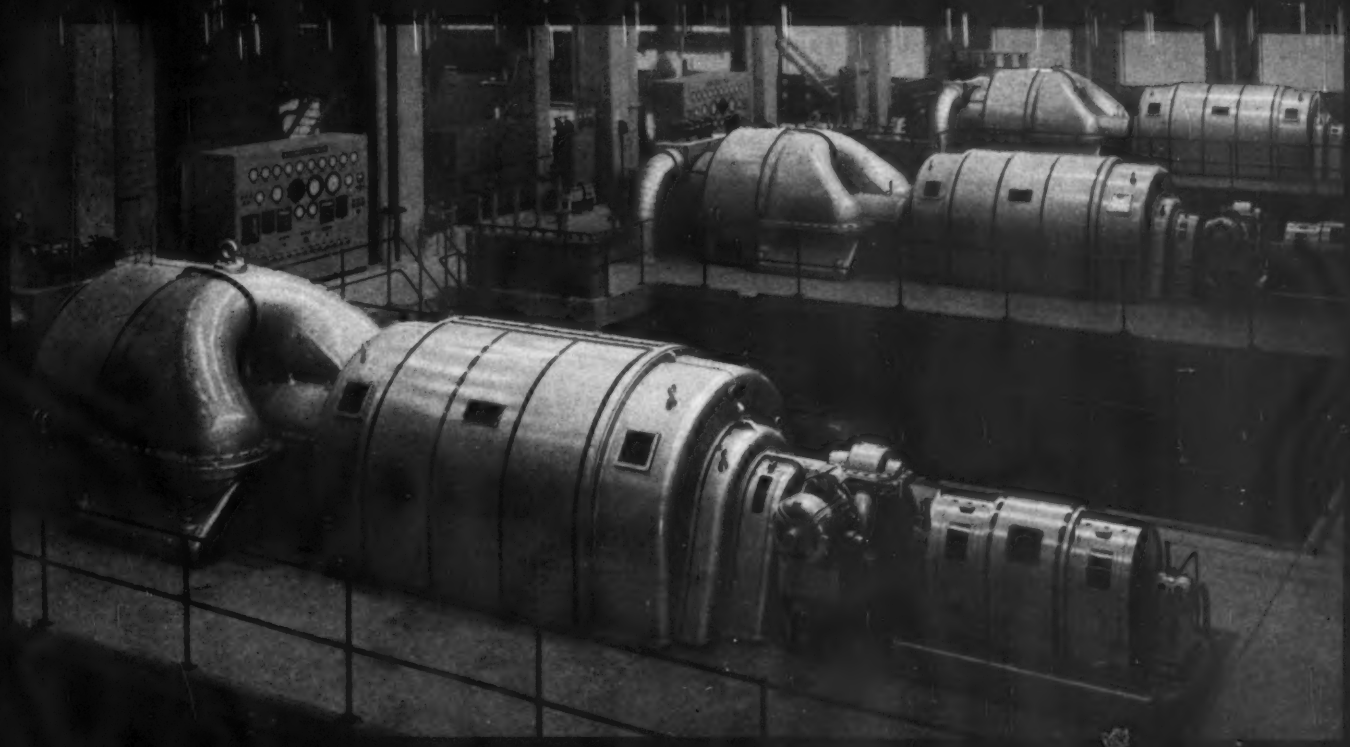
steel

Ravenscraig, near Motherwell in Scotland, is the site of the latest and most important addition to the iron and steel industry of Scotland to which Colvilles Ltd. have already contributed so much.

Here, from an undeveloped site, the first phase of this expansion, contributing more than a thousand tons of iron daily, was put into operation within three years. In this achievement the G.E.C. assumed responsibility for the whole of the power plant. This included the civil work, cooling towers, boilers, three turbo alternators, two turbine driven blast furnace blowers, two turbine driven pumps, and all associated switchgear, transformers and ancillary equipment to control the gas, steam and electric supplies.

Electrical connection to the South of Scotland Electricity Board system and to other works of Colvilles Ltd. was also undertaken by the G.E.C.



The G.E.C. organisation, with its resources and experience is well able to undertake any such power project for industry or public utility, whether embodying nuclear or conventional thermal power source.

G.E.C. generators and blowers

THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND - HEAD OFFICE: MAGNET HOUSE, KINGSWAY, LONDON, W.C.2.

8 good reasons why you should use these ROLLER GUIDES in your bar or wire rod mill

Nos. 125 and 155 roller guides fitted in a 27 1/2 in. (700 mm.) diameter, three-high stand for rolling 2 3/4, 3 3/16, 3 9/16, 4, 4 3/8 and 4 7/8 in. (70, 80, 90, 100, 110 and 124 mm.).

1 The entry friction guides are rigidly clamped into the guide box. They are intended to lead the oval to the groove in the roller, to protect the rollers against overloading, and to straighten bent rods.
The groove in the entry guides is made about 1/8" wider than the oval.

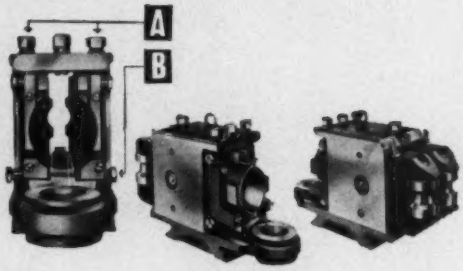
2 The rollers are mounted on leaf springs, which can be adjusted by means of the screws "B", and hold the oval steadily even if there should be some slight variation in the thickness of the oval.

3 If the thickness of the oval should vary, the springs of both rollers yield an equal amount, so that the oval remains in the centre of the groove.

4 To tilt the oval, the screws "A" are adjusted. One roller will then be lifted as much as the other is lowered.

5 As the oval is held very rigidly, the leader oval for wire rod may be thick, unless other circumstances call for a thinner oval.

6 The roller guide assemblies are narrow, and all screws that require adjustment during rolling are accessible from the front of the mill. No lateral space outside the guide box is therefore required for gaining access to the set screws, and the guide box assembly can thus be located close to the mill housing.



7 As the groove in the entry guides is wide and nothing but rolling friction acts on the oval, the latter is very easily introduced into the pass, and there is practically no risk of scratching the bar.

8 The roller guide may be used not only for leader and drawing oval passes but also for edging flats as well as for rolling squares, hexagons, octagons and various other sections, for instance in reduction passes for hexagon. It is suitable for all types of rolling mill. An important advantage is that the roller guide enables repeaters to be used in rolling plump leader-ovals.

PS *Practically speaking, every bar and wire rod mill in Scandinavia uses roller guides of our design.*

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In 1955 Birlec installed Britain's first furnace of this design and has orders for a further score from foundries engaged in the production of castings in aluminium, brass and bronze, and iron and steel. These units range in capacity from 12 cwt. to 15 tons, the latter being amongst the largest coreless induction melting furnaces in the world.

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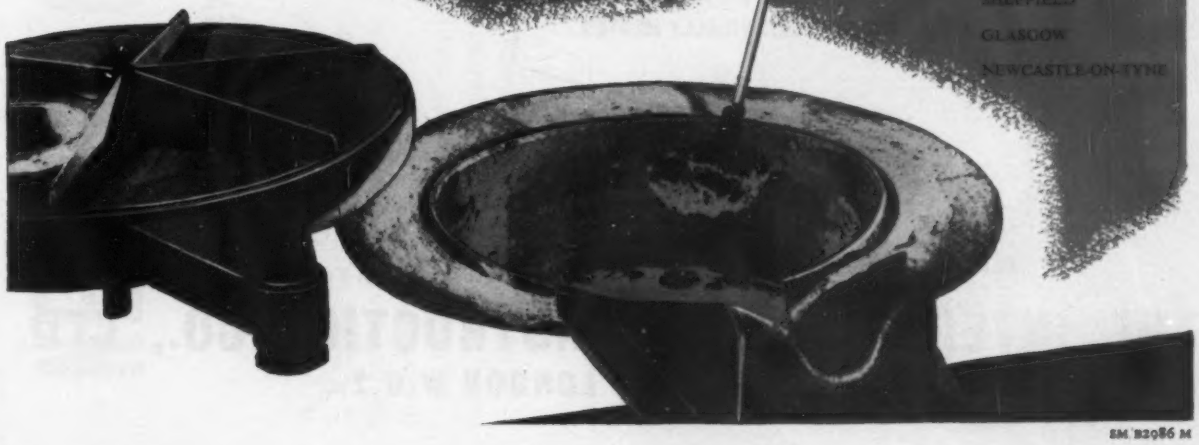

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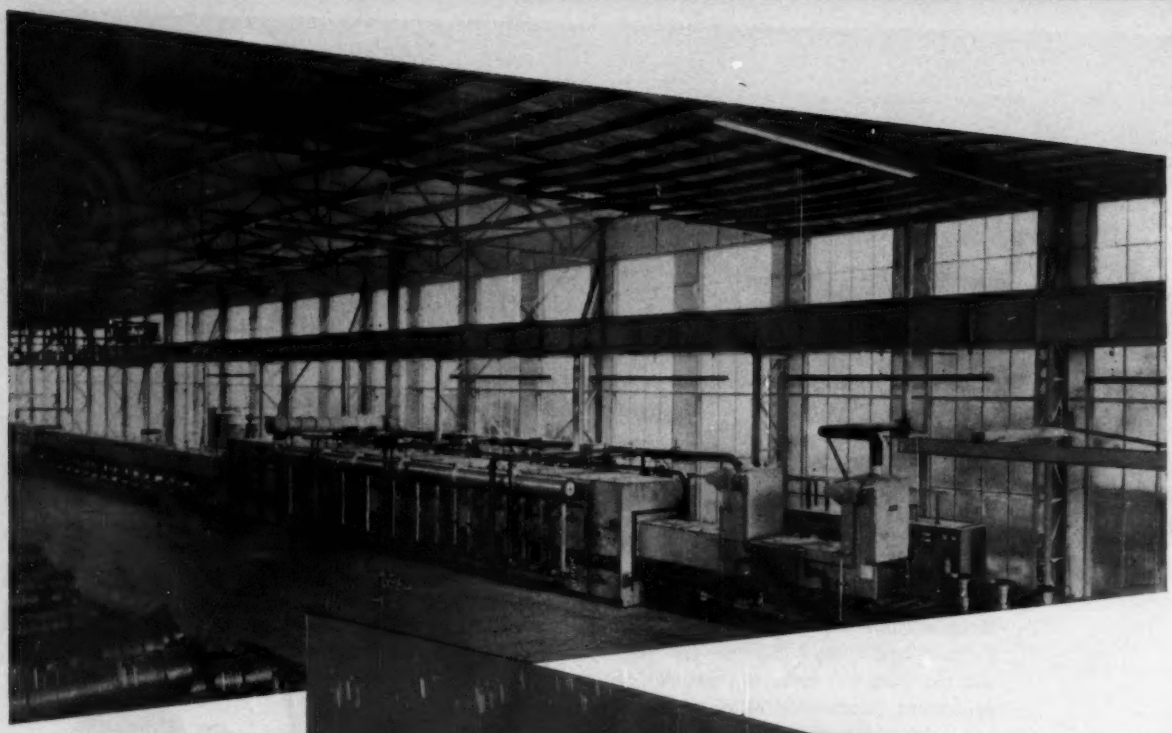

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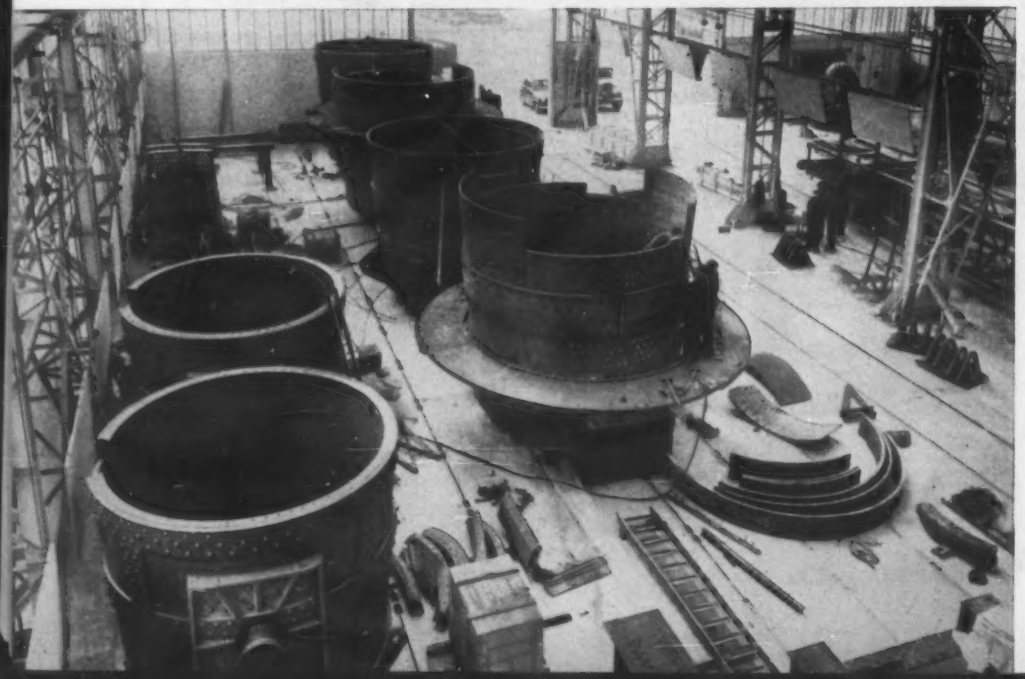
We bring to the service of the steel industry years of specialised design and manufacture of steelworks plant and equipment and we are to-day one of the largest suppliers of steelworkers ancillary plant, including ladles up to 300-tons capacity.

BELOW *275 ton ladles under construction at Thorncliffe.*



RIGHT *One of many steel casting ladles supplied to John Summers and Sons Limited.*

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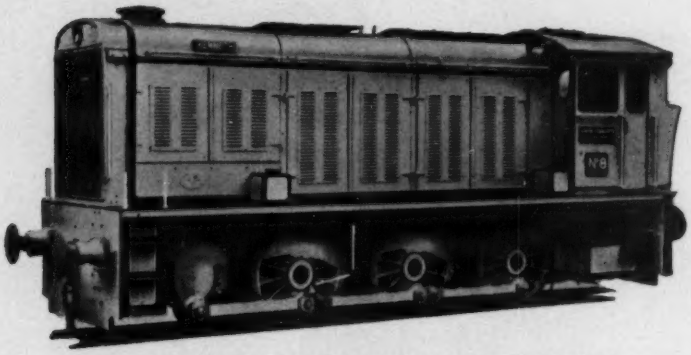

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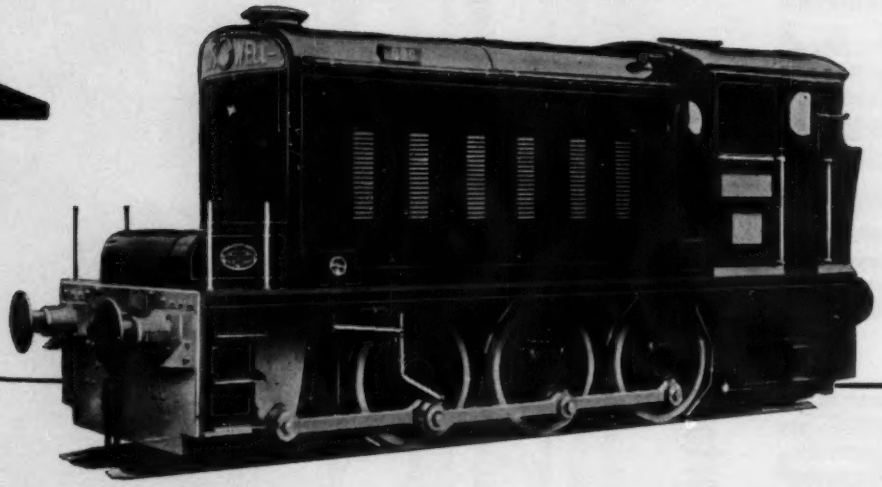

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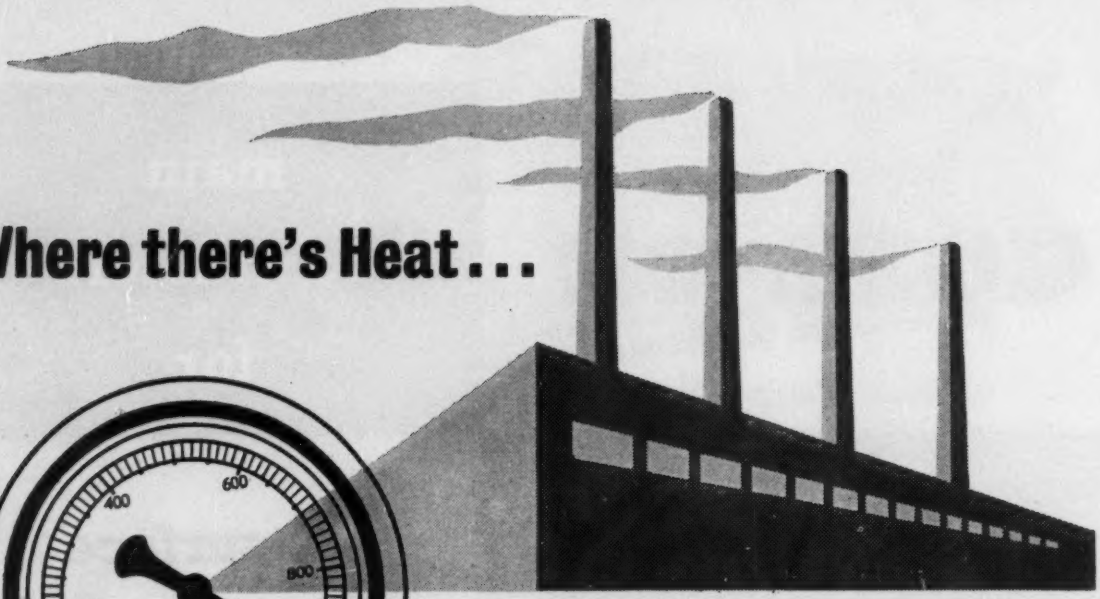
Where there's Heat...



BPL Heat Resisting Paints

When heat plays a part in production — whatever the industry and equipment employed — there is the need for BPL Heat Resisting Paints for the protection and decoration of plant. Furnace doors and boiler-room equipment, surfaces of high temperature reaction vessels, smoke stacks, foundry plant, exhaust manifolds; these are examples of quite usual applications, but perhaps your particular industry has unusual problems to be solved.

As the choice of coatings is limited, especially where temperatures are in excess of 600°F., and these treatments are expensive, we strongly urge you to discuss your requirements with our Technical Advisory Service.

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FINISH REQUIRED	TEMPERATURE RANGE	PRIMER	SECOND COAT	FINISHING COAT
Gloss Finish (interior or exterior)	Up to 350°F.	B.P.L. Heat Resisting Primer (M.P.34)	B.P.L. Heat Resisting Undercoat	B.P.L. Heat Resisting Enamel
Metallic Finish (interior or exterior)	Up to 400°F.	B.P.L. Heat Resisting Primer (M.P.34)	'Mettal' (Thermal) Aluminium Undercoat	'Mettal' (Thermal) Aluminium Finish
Bright Aluminium (interior only)	Up to 850°F.	'Lumeros X' Aluminium	—	'Lumeros X' Aluminium

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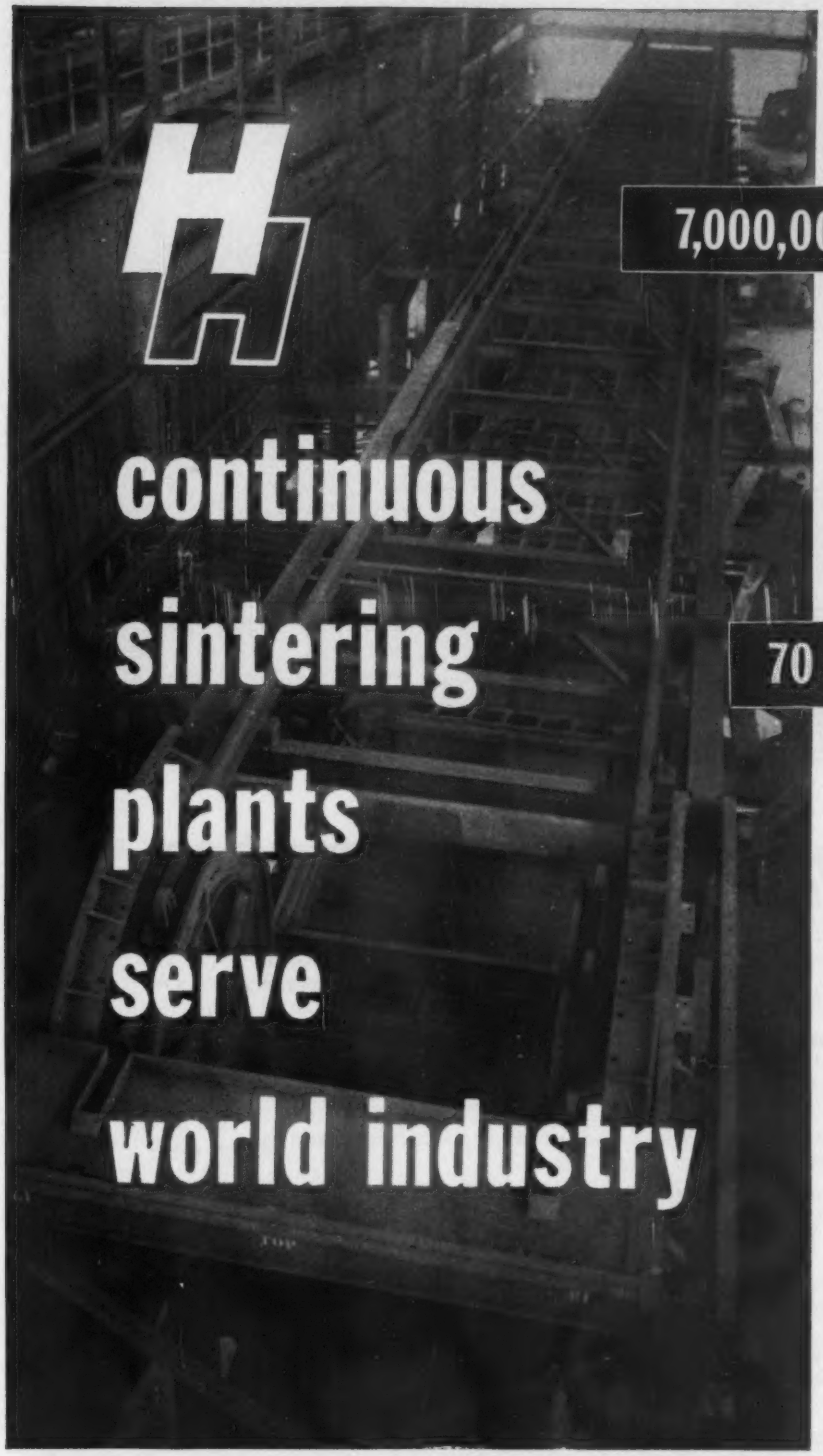

A Huntington Heberlein sintering plant under construction

7,000,000 tons per year

Seven million tons of sinter per annum is the impressive aggregate output of the fifteen sinter plants ordered by iron and steelworks at home and abroad from Huntington Heberlein since the beginning of 1955.

70 years' experience

Behind the design of these plants, in Britain, France, Belgium and South Africa, is some seventy years' experience of the sintering process which is coupled with an up-to-date knowledge of the latest techniques and potentialities of the process.

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Other specialities include:
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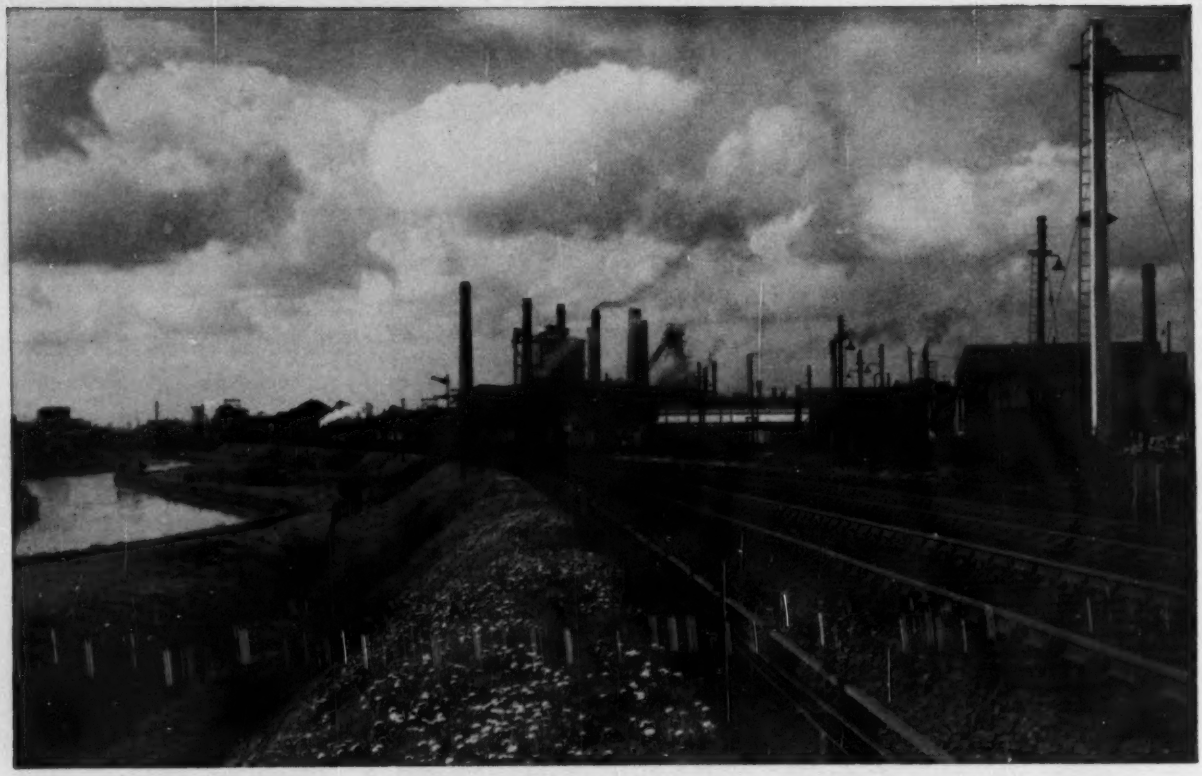

Staffordshire Landscapes

Over 100 years ago, sturdy horses tramped the banks of these canals, moving a steady flow of materials and products to and from Black Country Iron Works and Foundries.

As the new railway spread its net-work the passage of goods moved gradually from water to rail. Today, the busy lines, often following the easy contours of the old waterways, drive into the hearts of the factories.

The weed strewn highways of last century remain witnesses to the relentless advance of new ideas.

Progress in Staffordshire, bringing almost every major improvement in the technique of iron-founding since 1700, is apparent in the landscape of the County as well as in its products.

For almost a century and a half Pig Iron has been manufactured at Darlaston Iron Works. Today, the most modern methods of metallurgical control of raw materials and the finished product, enables them to supply Pig Iron of consistent uniformity to the most exacting specification.

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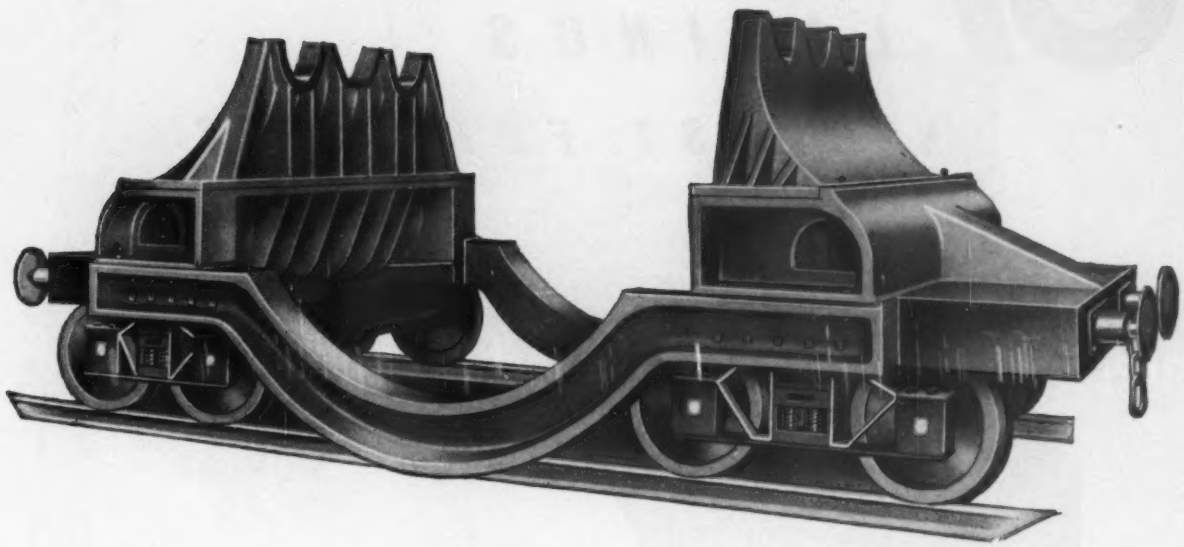

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We shall be glad to quote against your requirements and specifications.

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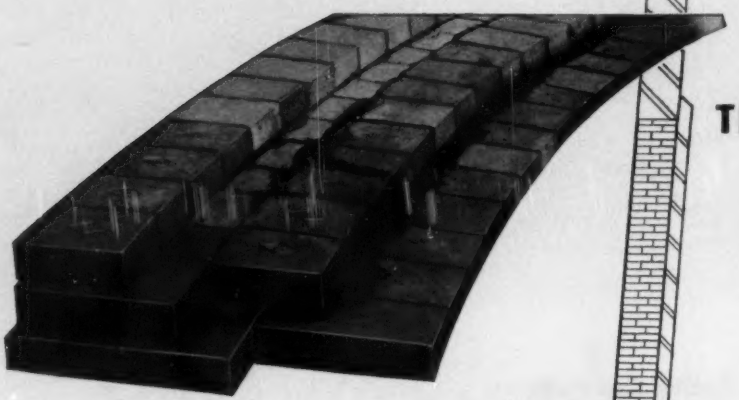
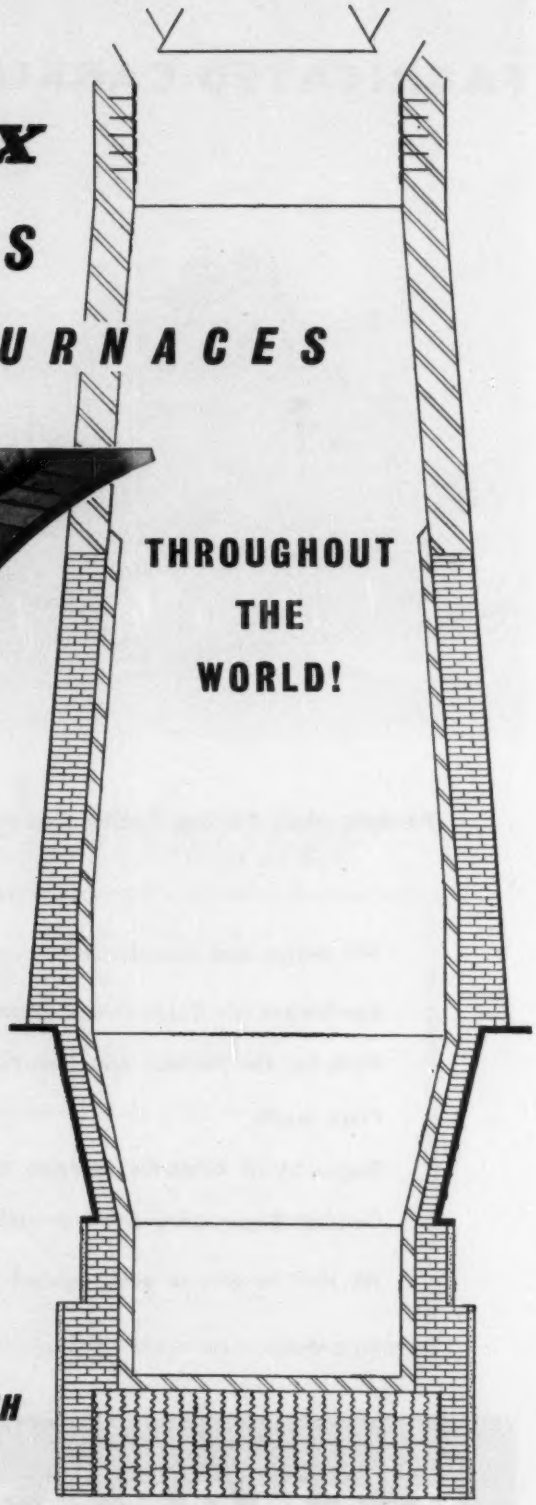
87 CARBLOX LININGS IN BLAST FURNACES





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for the WELL WALL, BOSH and HEARTH

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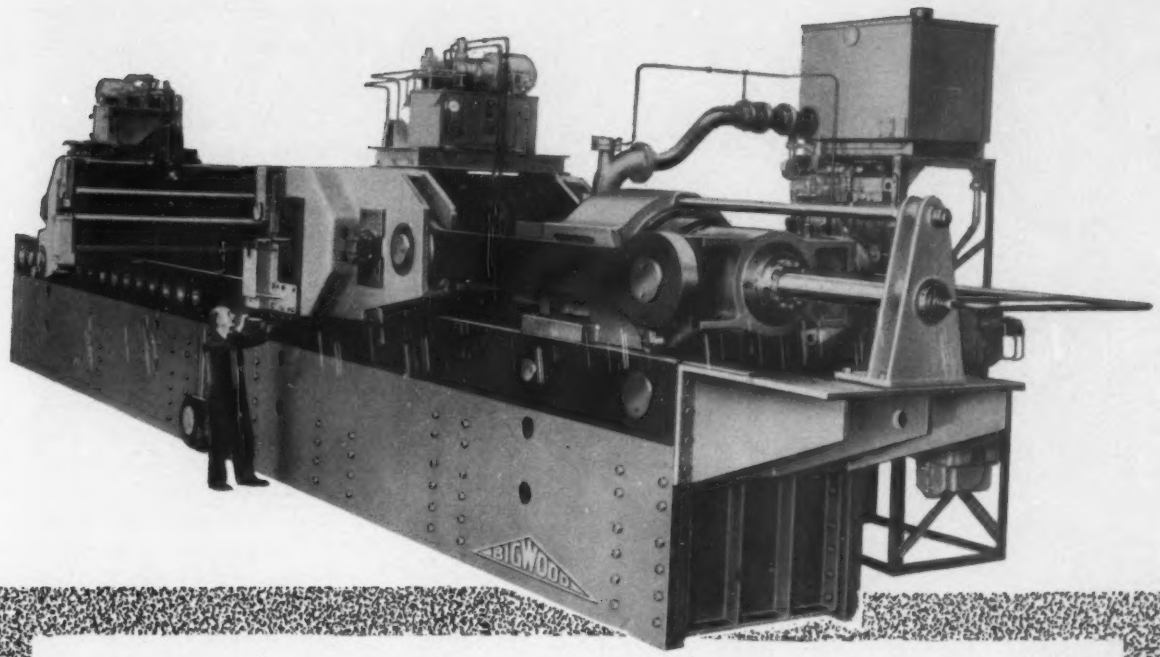

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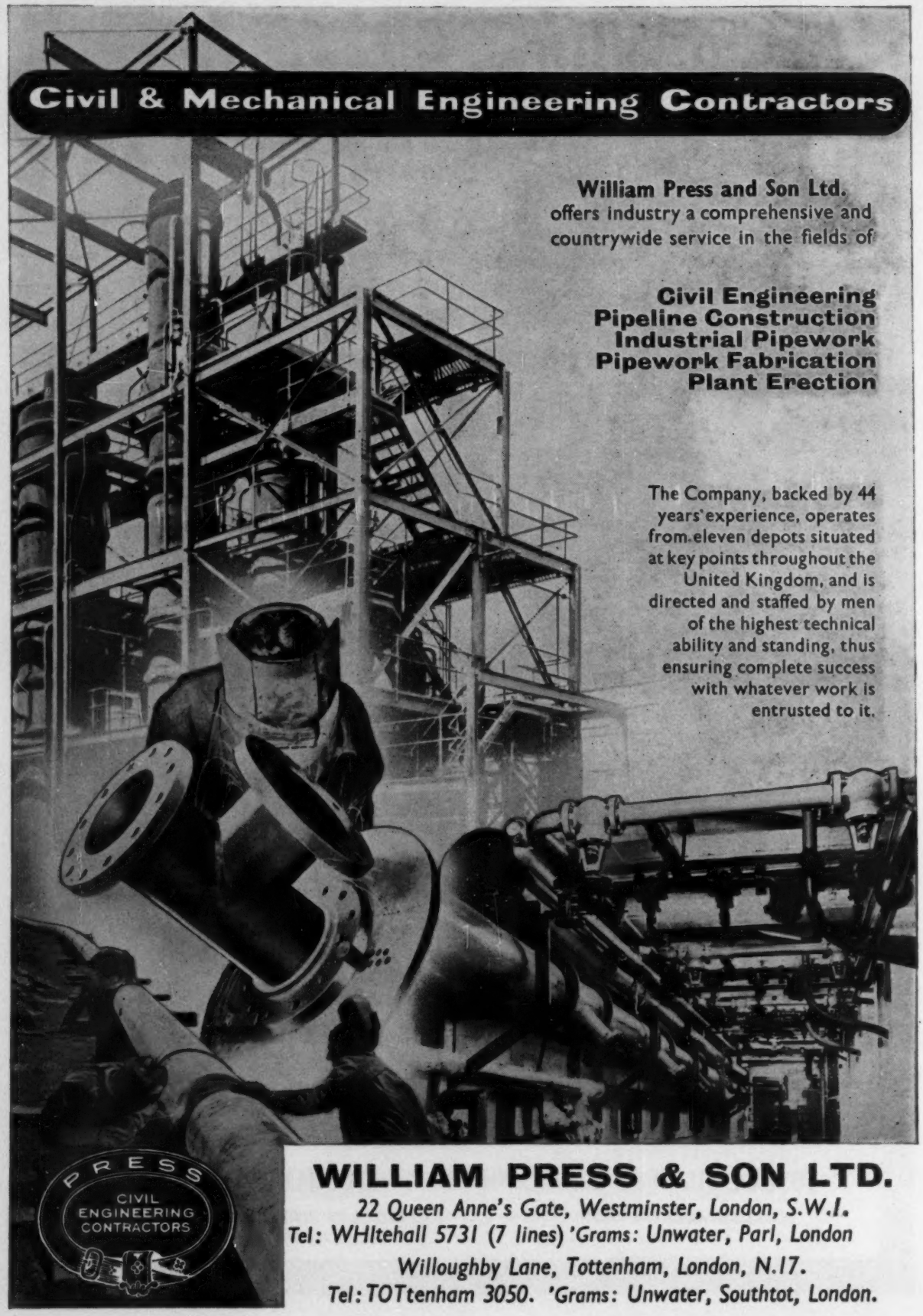
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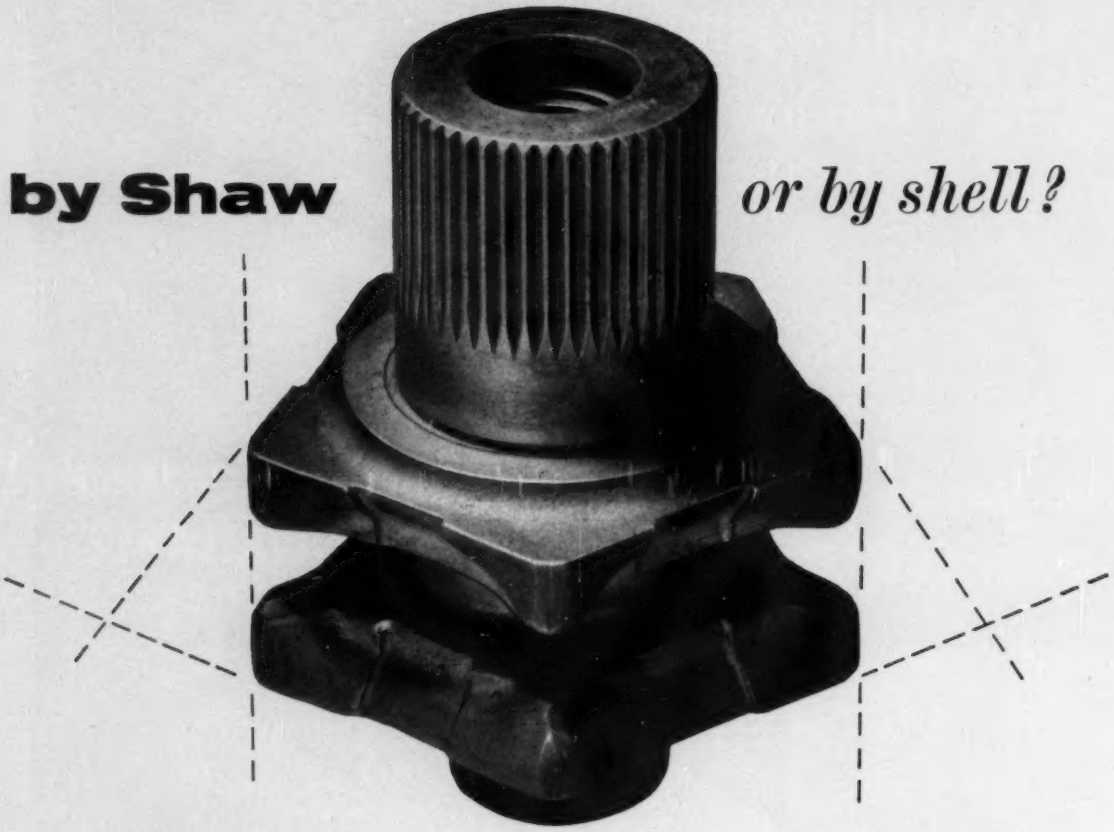
by Shaw *or by shell?*



As licensees of the Shaw Process, and producers of castings by the Shell Moulded Process as well, The PHOSPHOR BRONZE Co. Ltd. can give you an unbiased opinion on the best method to use in any instance. While castings produced by the shell moulded process are more accurately produced than by older methods, the limits cannot be held to the same high degree of accuracy as when castings are produced by the Shaw Process.

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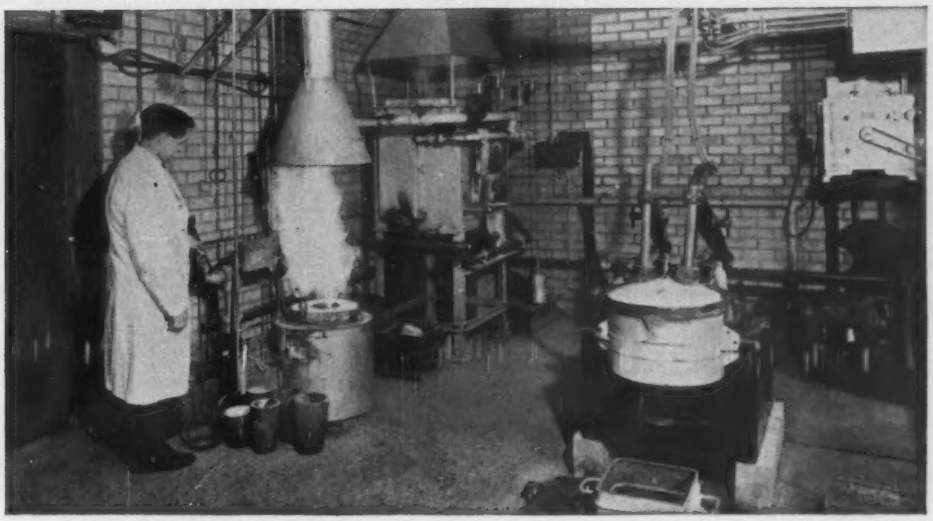

answer to

If you should be faced with a technical problem in connection with casting defects in foundry sands, you are invited to call on the facilities of our experimental foundry and sand testing laboratory. In addition, our foundry technicians will be pleased to visit any foundry man who might wish to discuss a particular difficulty on the spot. These 'Fulbond' services are offered without charge and are, of course, entirely confidential. If you will kindly telephone or write to us, we shall be very pleased to co-operate in finding the answer to your problem.

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TRI-MOR *Standard Castable*

A medium texture refractory having negligible shrinkage up to 1,350°C. Suitable for casting special shapes or for monolithic structures. Limiting service temperature 1,350°C.

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A similar refractory to Tri-Mor Standard Castable, but specially developed to have very high mechanical strength over the lower temperature range. Maximum service temperature 1,250°C.

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Suitable for face temperatures up to 1,600°C; has an extremely high resistance to thermal shock; used for cast in situ monolithic structures and for pre-cast refractory shapes; can be applied with a cement gun.

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A hydraulic setting refractory with a maximum service temperature of 1,300°C. It has a high resistance to abrasion. Designed for application by cement gun, but can be trowelled.

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An insulating castable for maximum service temperatures of 1,200°C; low thermal conductivity is its main feature.

TRI-MOR *Insulating "Guncrete"*

Similar to Tri-Mor Insulating Castable but for application by cement gun.

Full details of each grade are available on request.

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For further information please write to: MORGAN REFRACTORIES LTD. NESTON, WIRRAL, CHESHIRE. TEL: NESTON 1406

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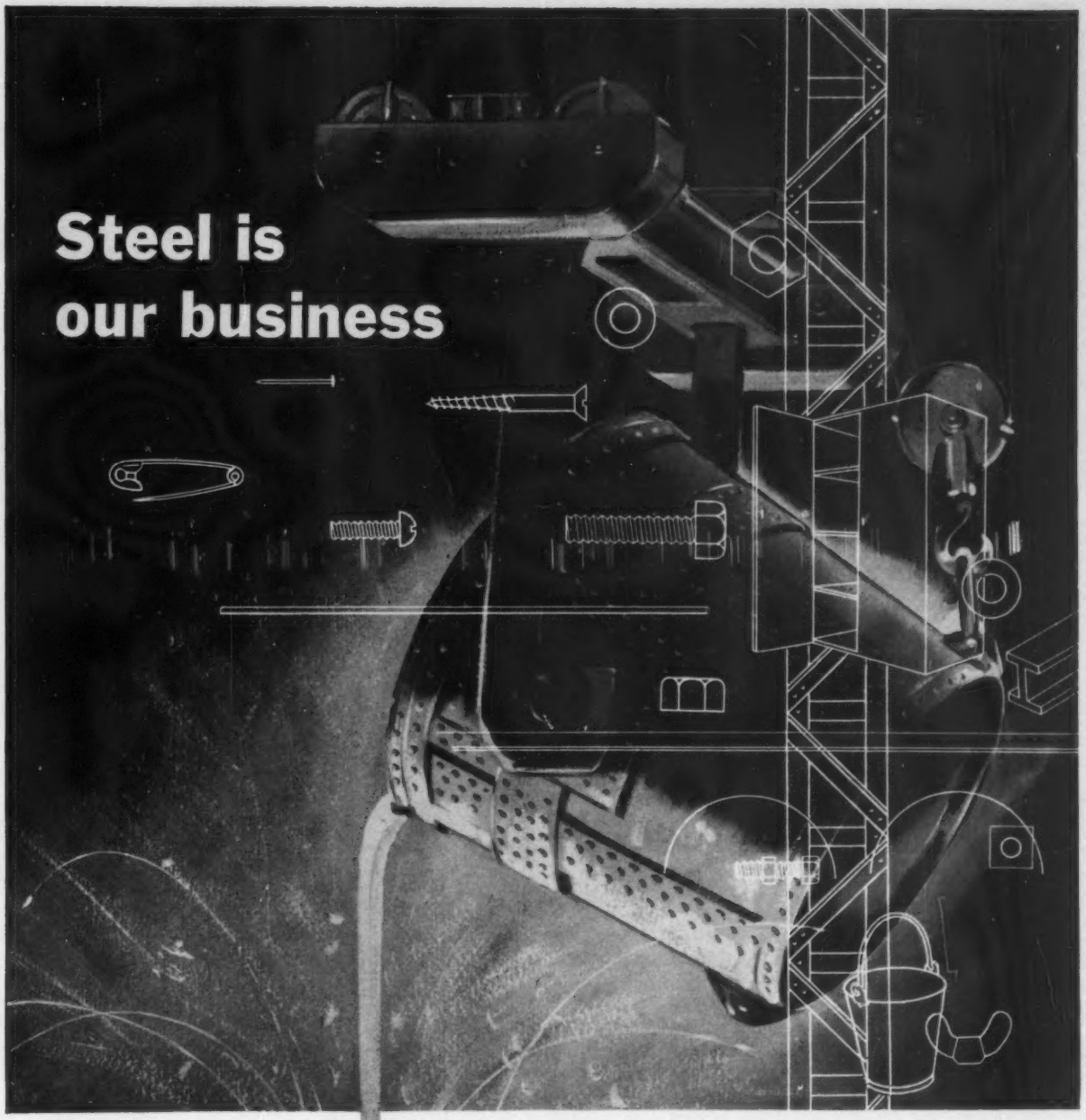

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Modern control gear for the Metal Industries

Photograph by permission of Richard Thomas and Baldwins.

An installation incorporating 300 ft. of 'ENGLISH ELECTRIC' control boards for the operation of the new continuous galvanising line at Richard Thomas and Baldwins' Ebbw Vale Works.

The future of the Metal Industries depends more than ever on the up-to-date design of control gear. 'ENGLISH ELECTRIC' have developed power and control schemes for leading rolling mills throughout the world for more than half a century.

Still pioneering today, the Company's engineers offer new techniques including:

Fully automatic programming for hot reversing mills

Automatic gauge control and slow-down for cold mills

Comprehensive control for all process lines.

If you have a problem on control gear, 'ENGLISH ELECTRIC' experience is available for its solution.

'ENGLISH ELECTRIC'

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

Metal Industries Division, Stafford

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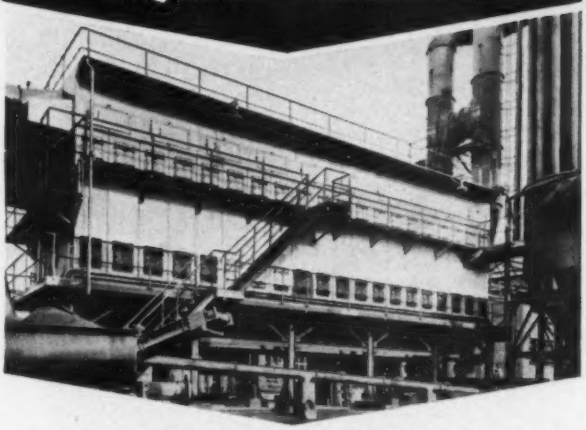

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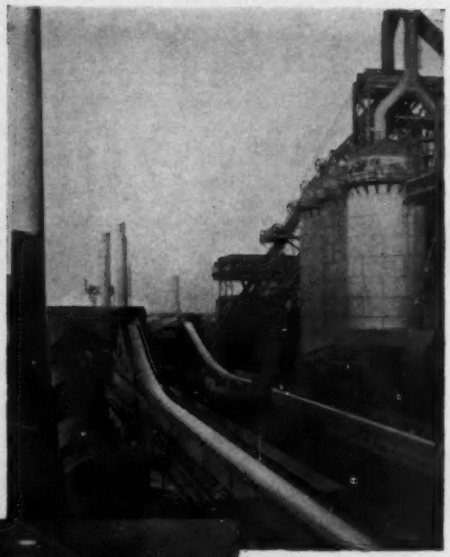

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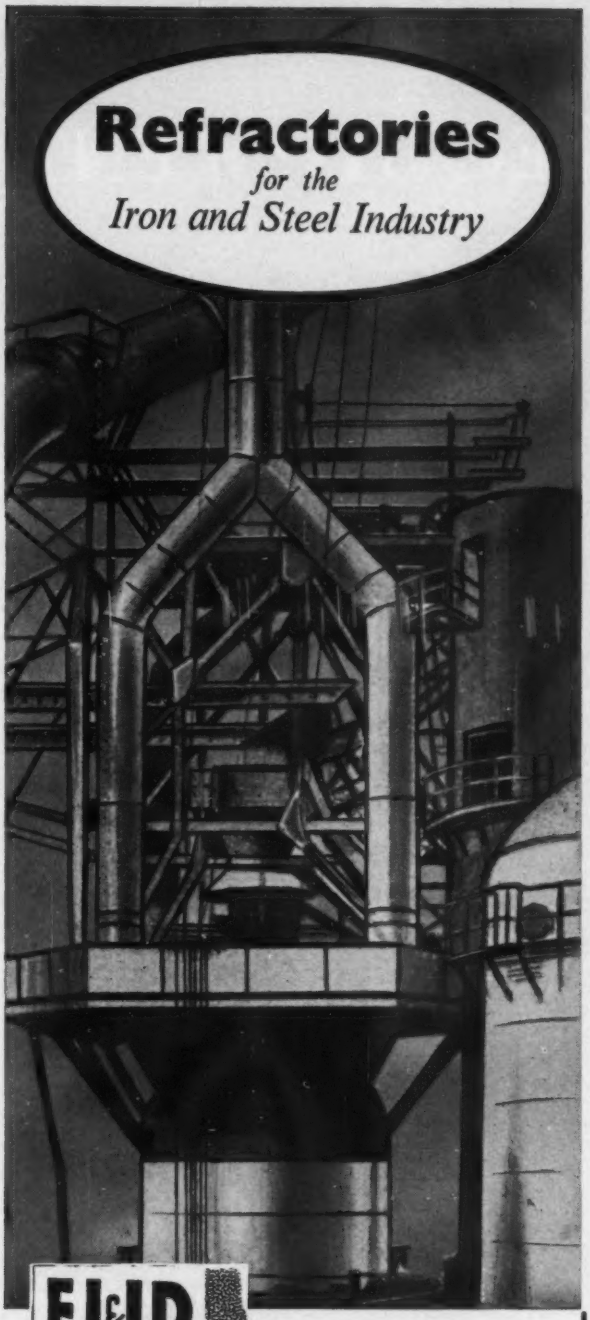

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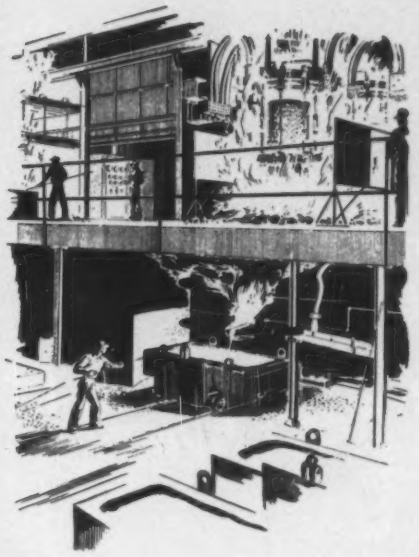

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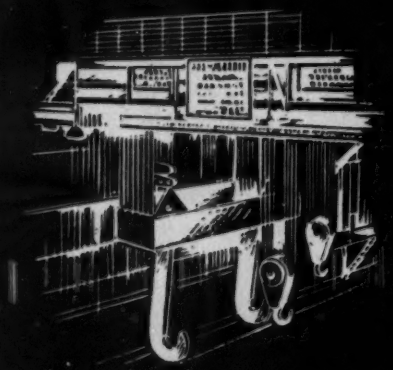
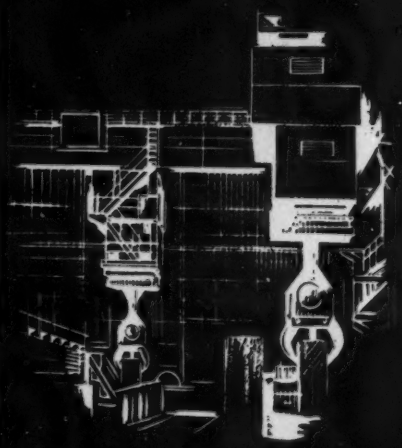
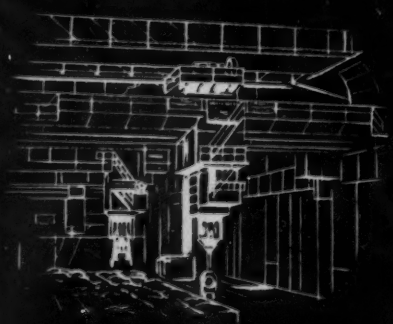
STEELWORKS EQUIPMENT



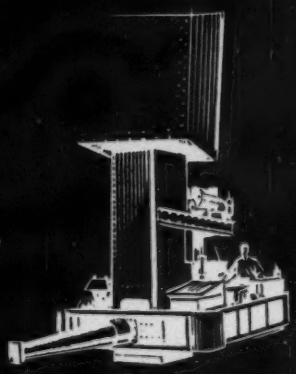
Ladle Cranes



Soaking Pit Cranes



Stripping Cranes



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September, 1958

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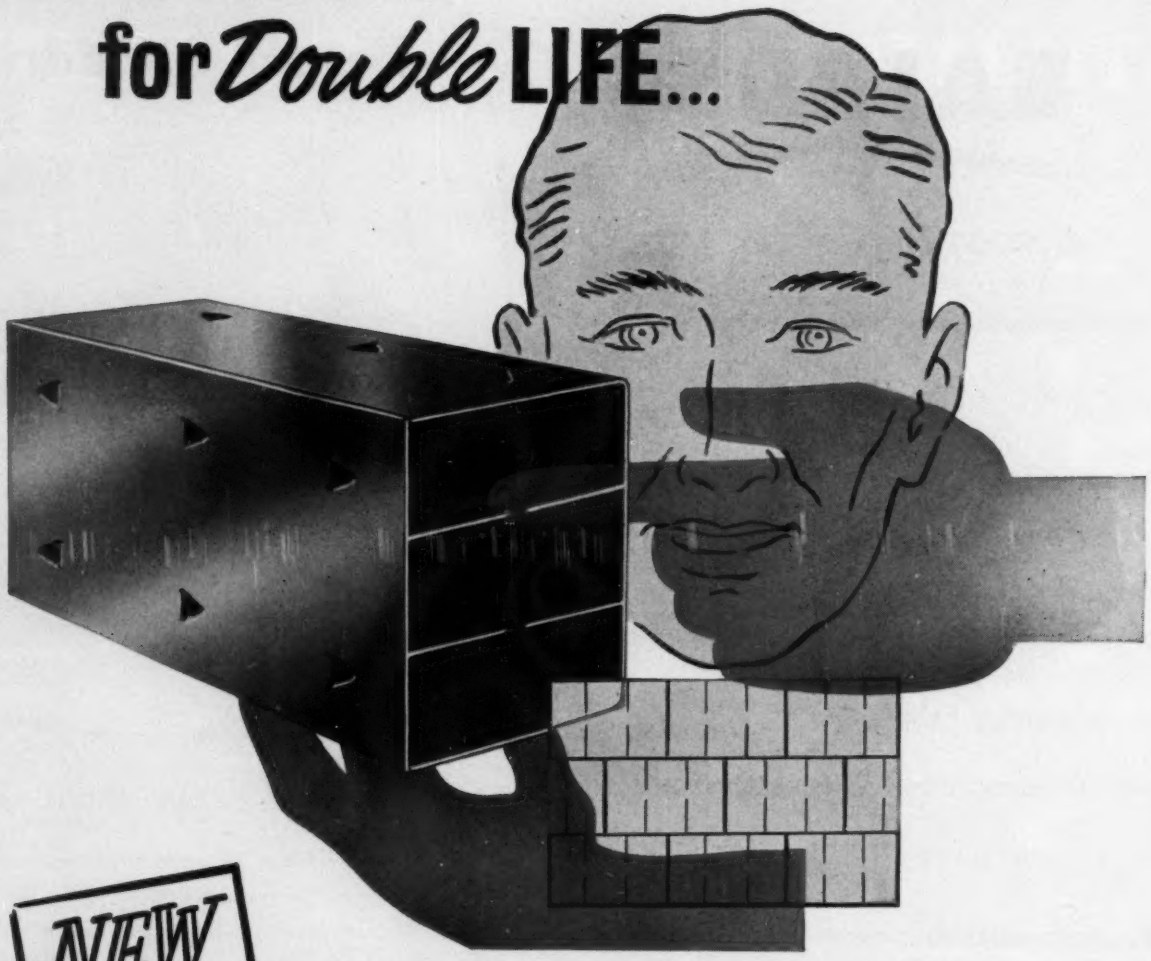
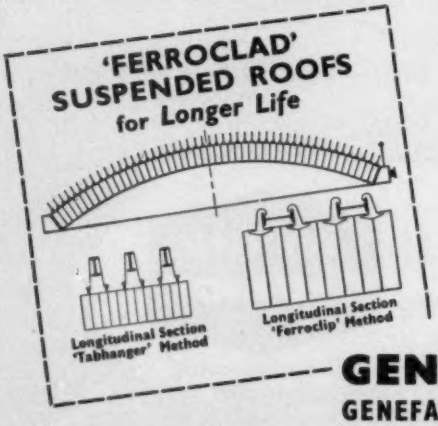
The *Double*-'E' for *Double* LIFE...



NEW

FERROCLAD 'EE' Design

eliminates Flaking and Spalling



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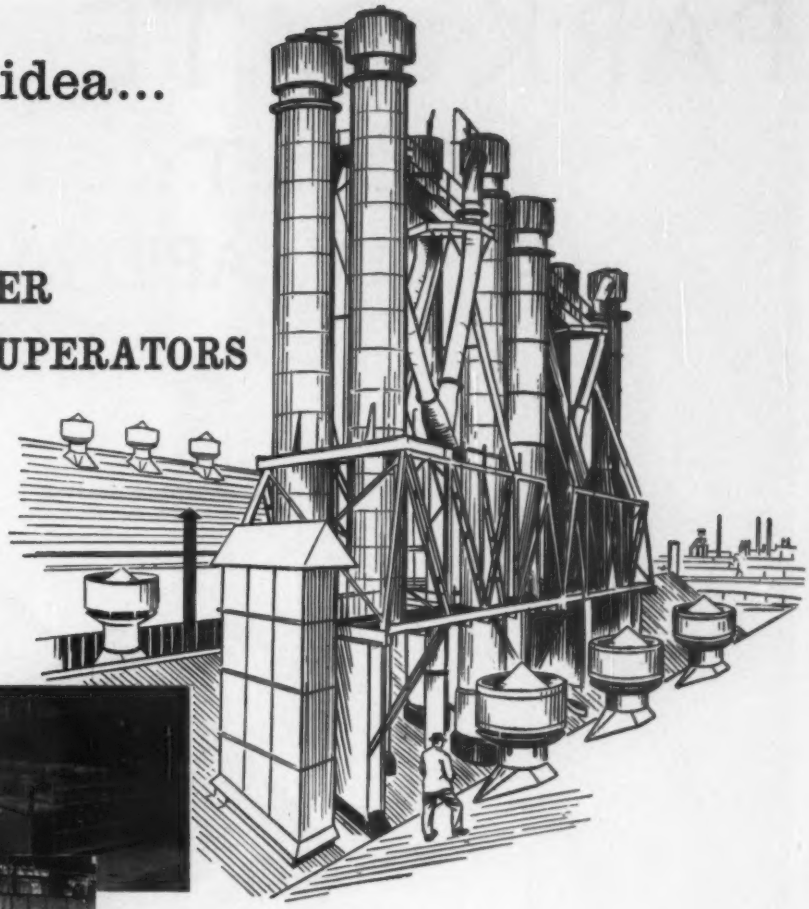
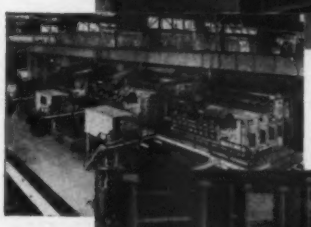


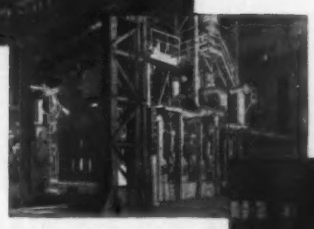
SOAKING PITS

CONTINUOUS FURNACES



FORGE FURNACES

BOGIE FURNACES



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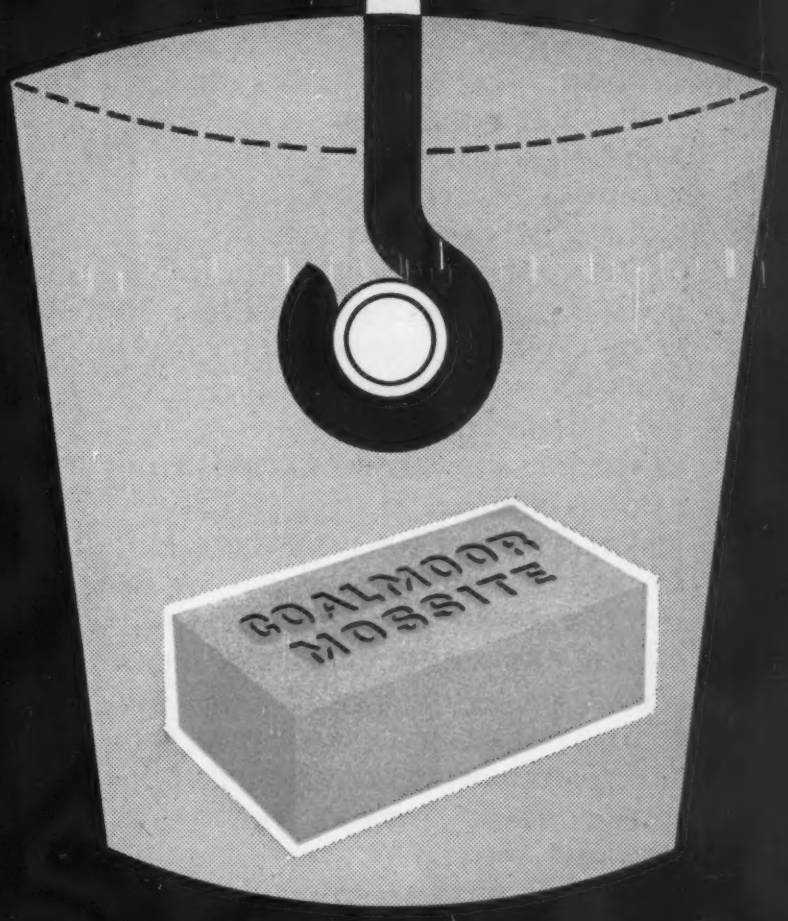

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R/LC/29/P.133

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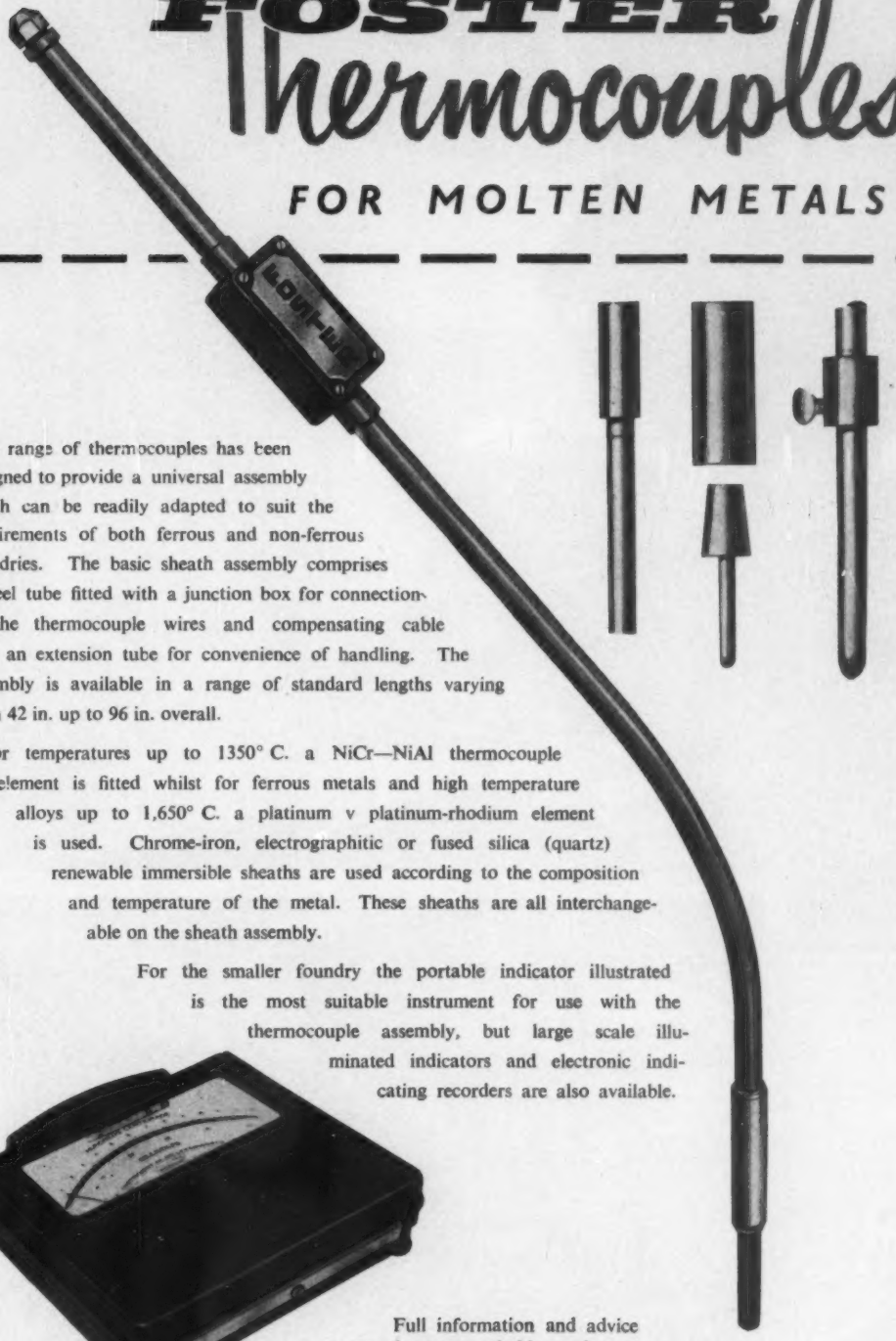

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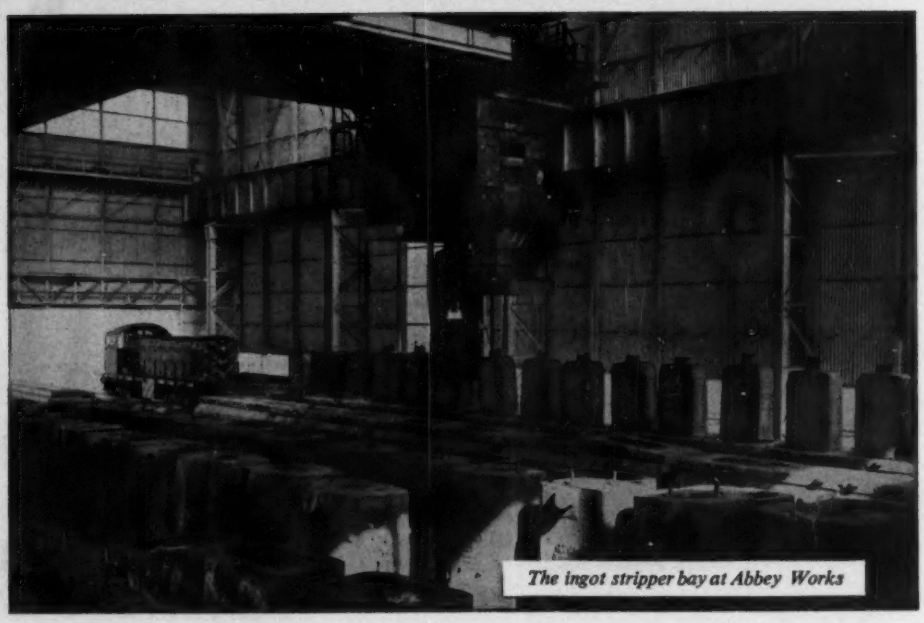

The ingot stripper bay at Abbey Works

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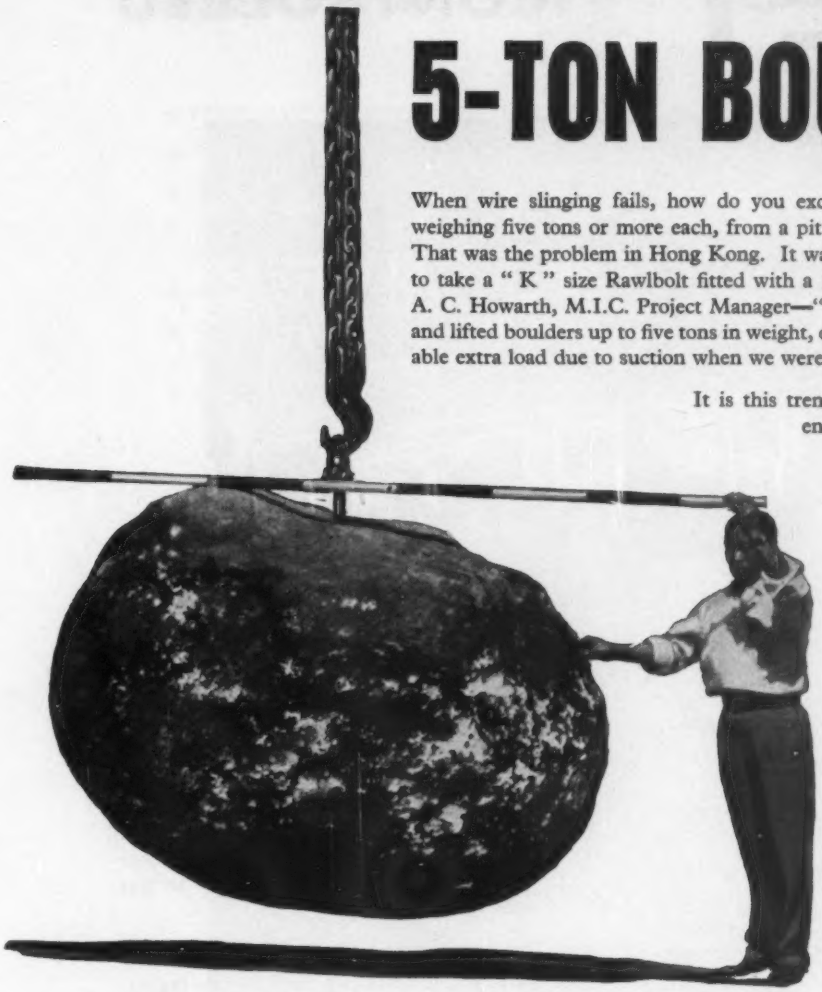

We are indebted to Messrs. George Wimpey & Co. Ltd., the Building and Civil Engineering Contractors, for the above information. The photograph was kindly provided by Mr. Howarth from the North Point Generating Station, Hong Kong.

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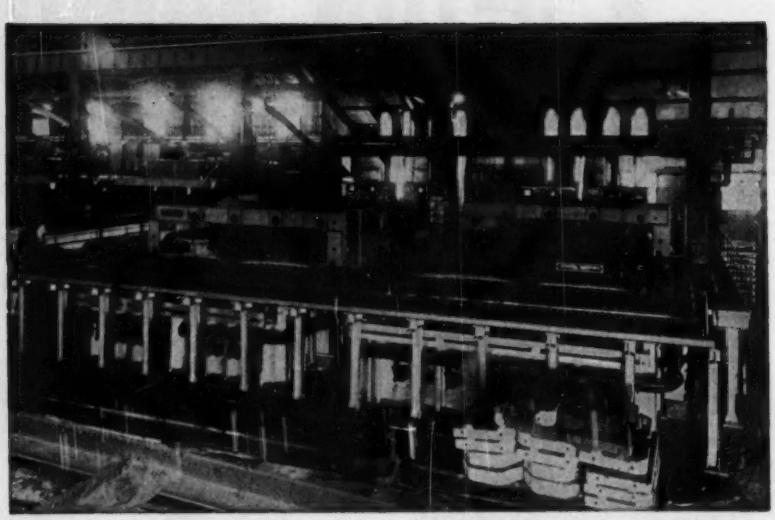

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Repeat order for 4-holes with fully automatic reversing control now in operation, making total capacity 180 four-ton ingots.

Further repeat order for 4-holes now in operation with complete fully automatic reversing equipment together with fully automatic air/gas ratio and draught control, and completely sealed covers, making a total holding capacity of 220 4-ton ingots.

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(5) Installation on N.E. Coast accommodating 160 3½/4-ton ingots, fired with blast furnace gas and having fully automatic reversal equipment and air/gas ratio control.

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Repeat order for 2-hole plant to accommodate 24 3/3½-ton ingots with fully automatic reversing equipment and complete automatic air/gas ratio and draught control with completely sealed covers.

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★ EXTREMELY SIMPLE CONTROL.

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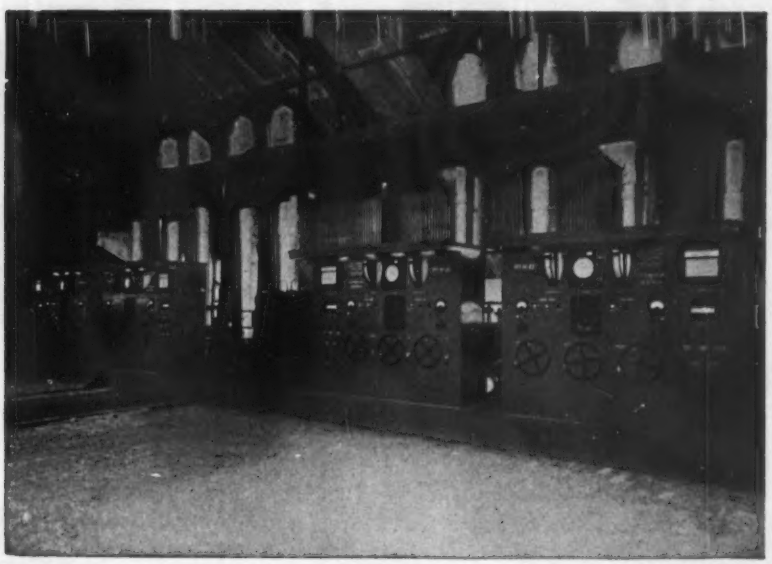
★ FULLY AUTOMATIC REVERSAL GEAR.



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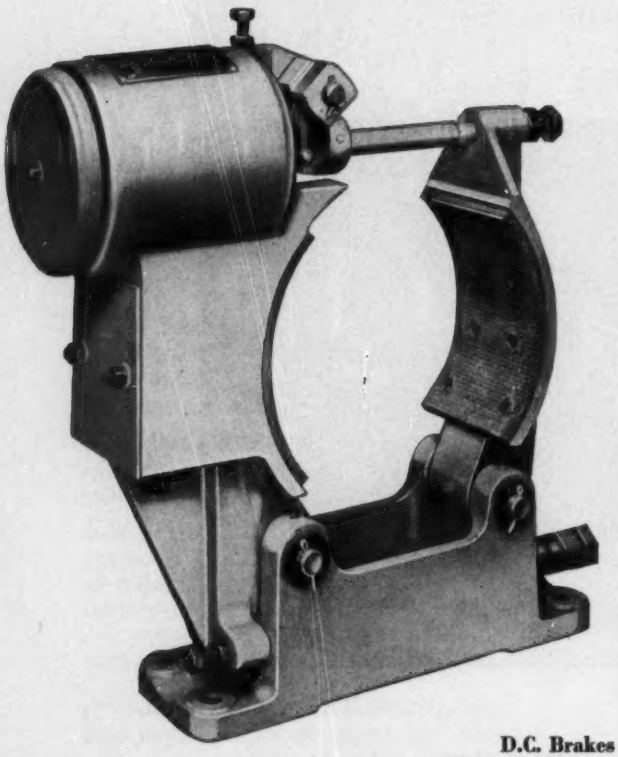

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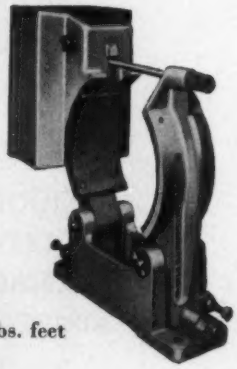

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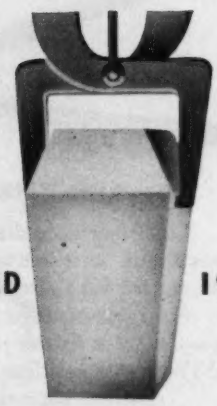

FITNESS FOR PURPOSE STEELS

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One of the many installations using KIP

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Photograph reproduced by courtesy of Appleby — Frodingham Steel Company (Branch of The United Steel Companies, Ltd.) and Stein and Atkinson, Ltd.

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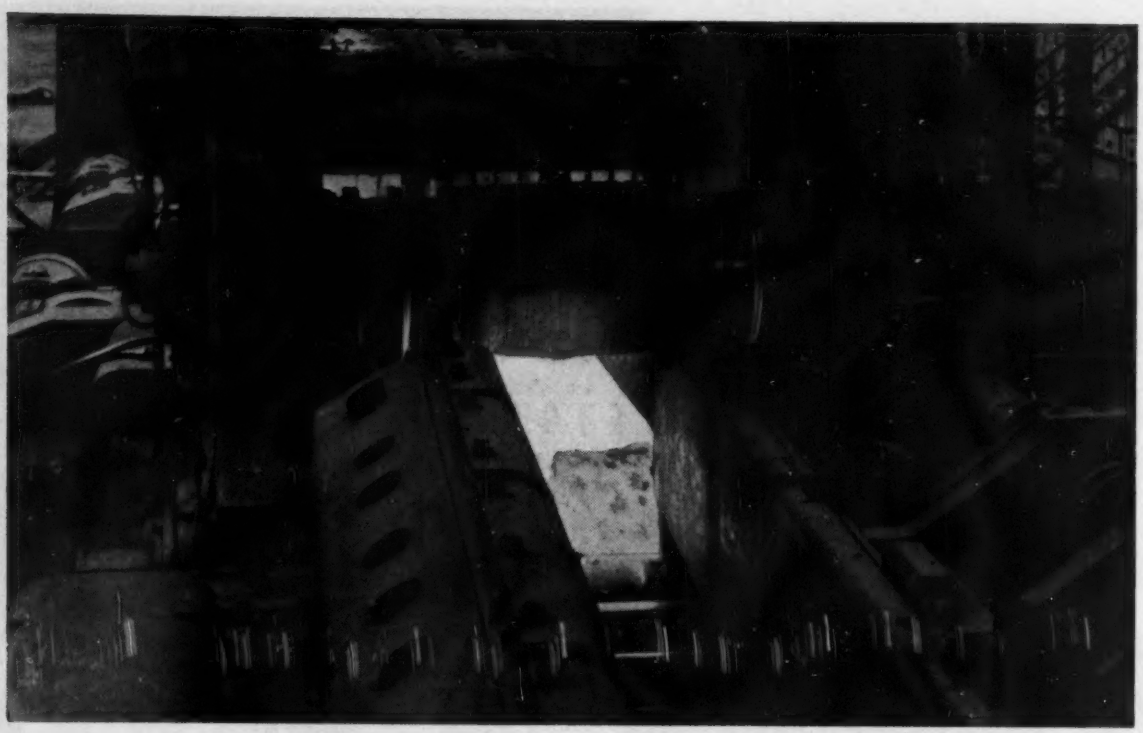

Slabbing and Blooming Mill at Consett.

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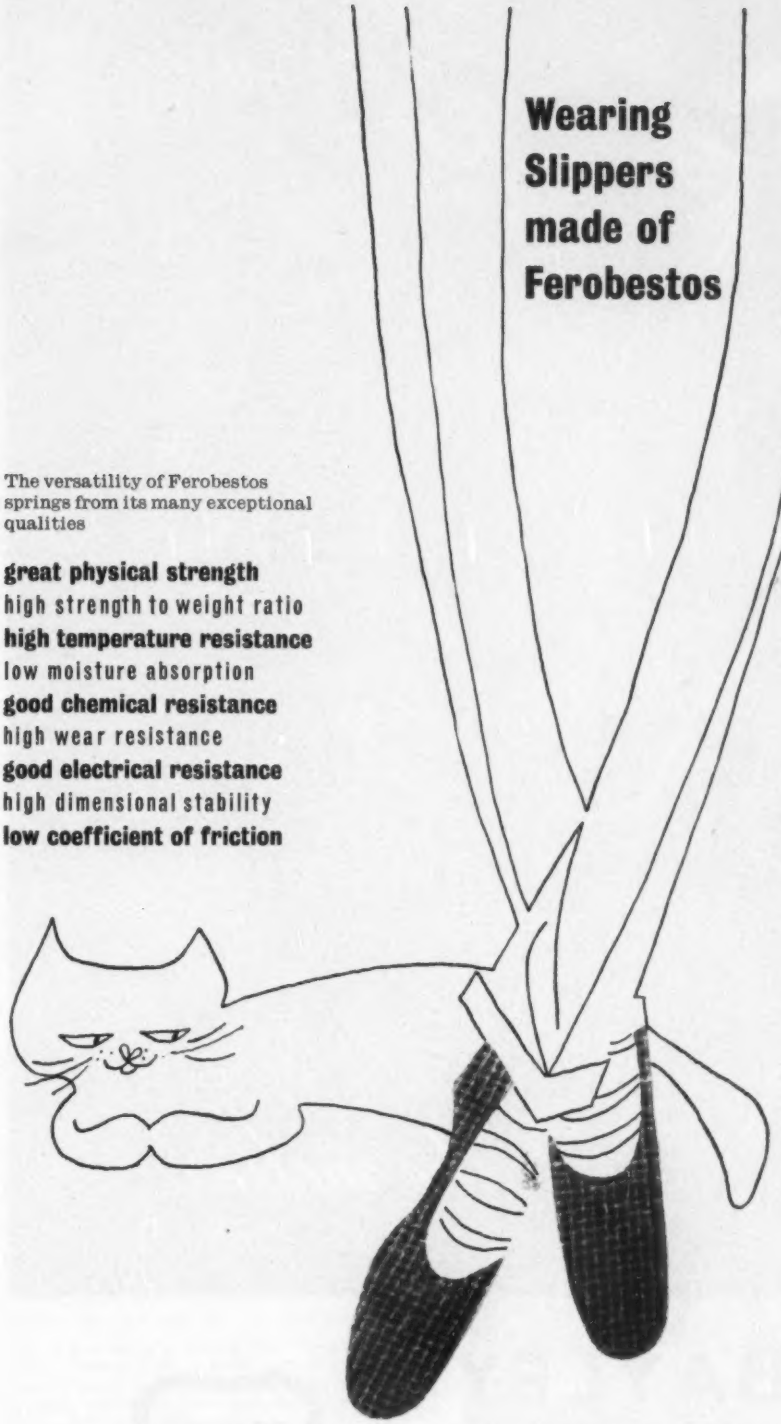

Wearing slippers is only one of the engineering applications of Ferobestos—the versatile, asbestos-reinforced plastic material. Here are just a few more of the ways Ferobestos can be used:—

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Piston Rings
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Ferobestos can be supplied from stock in sheets, rods, and tubes. Special mouldings can be made to order. We shall be glad to recommend and advise on the possibilities of Ferobestos as applied to any particular industry.

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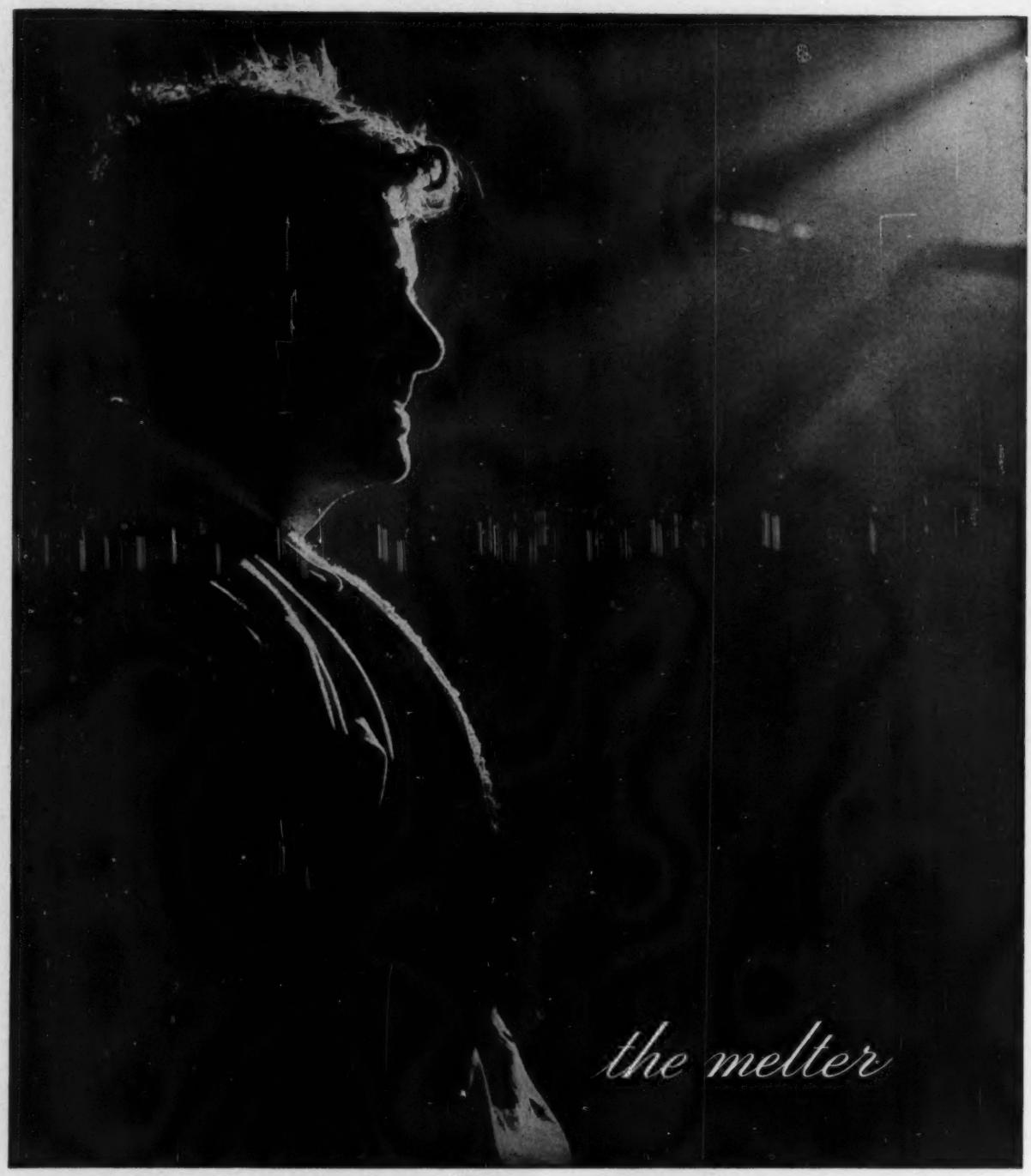

BROWN BAYLEY
STEELS LIMITED
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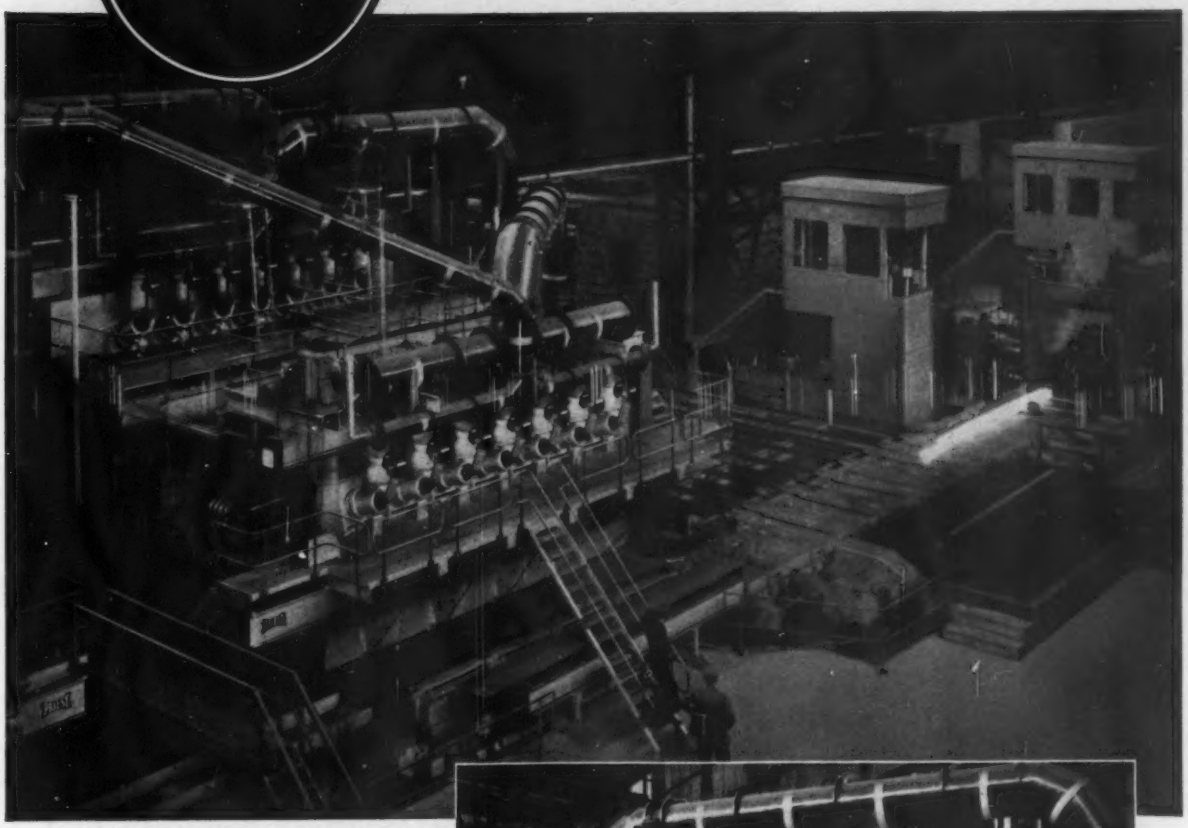
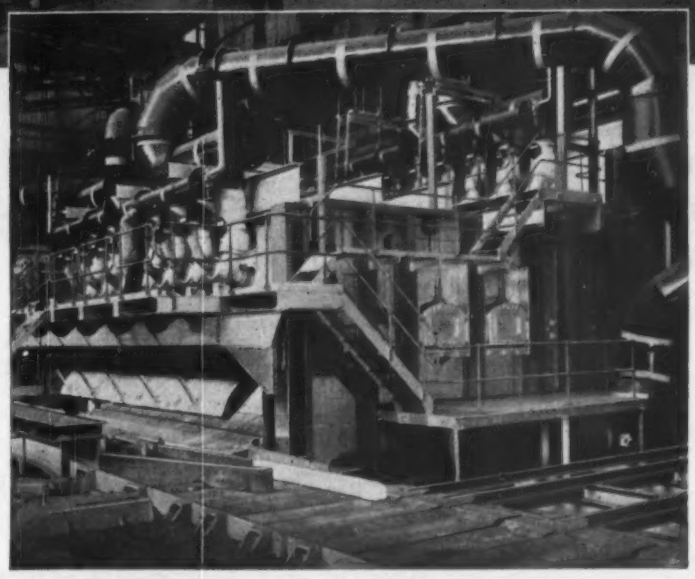
PRIEST

3 zone Bloom Re-heating Furnaces





The photographs show one of two Priest 3-Zone Continuous type gas fired recuperative Bloom Re-heating Furnaces for Medium Section Mill. Installed at the Cleveland Works of Dorman Long (Steel) Limited.

We also supply similar Furnaces for reheating slabs or blooms suitable for gas or liquid fuel firing.

We specialise in the design and construction of:—

Open Hearth Furnaces. Soaking Pits. Furnaces for Aluminium Melting, Coil Annealing and Slab Re-heating. Stress Relieving Furnaces. Forge and Heat Treatment Furnaces. Shipyard Plate and Bar Furnaces. Mould Drying Stoves. Modern Lime Burning Kilns.

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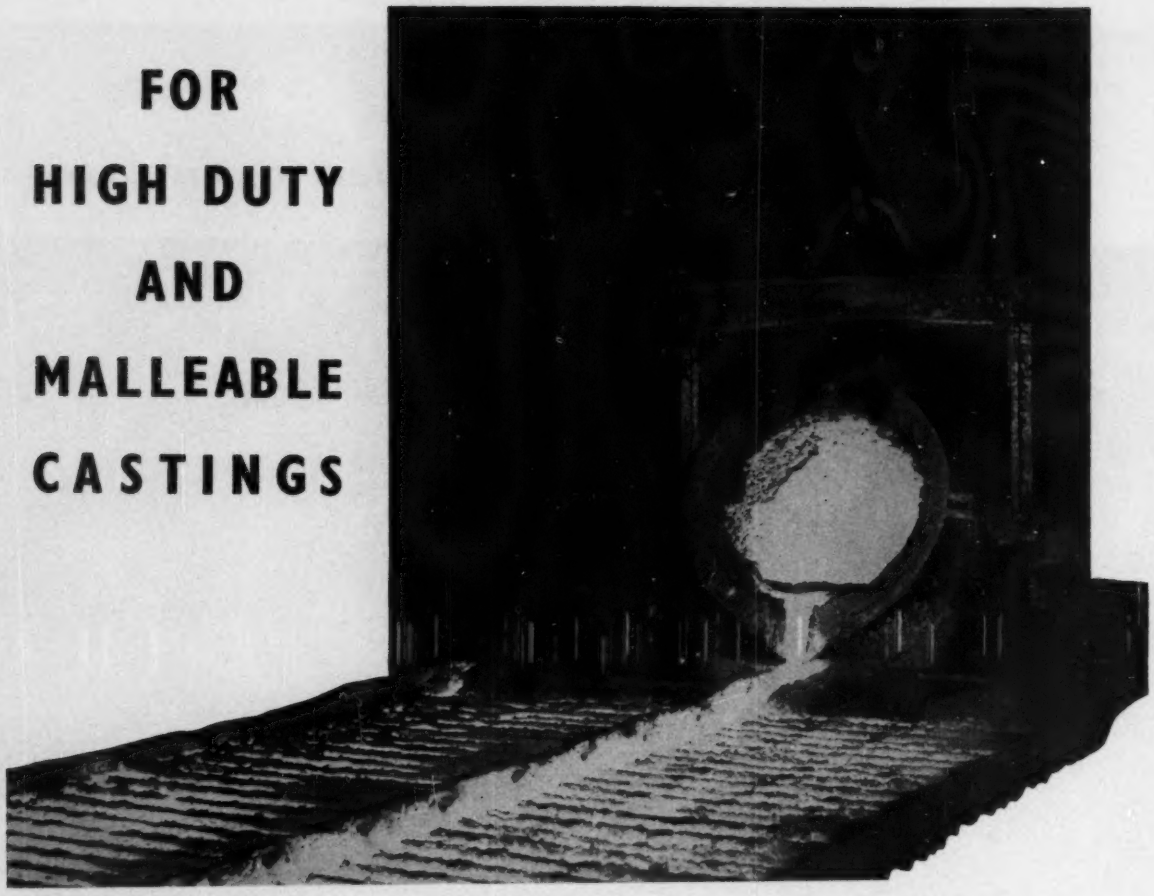


The seven standard grades of Stanton Dale Refined Pig Iron

GRADES:	A	B	C	D	E	F	G
SILICON %	1·9–2·1	1·4–1·6	0·9–1·1	2·25–2·5	0·9–1·1	1·4–1·6	1·9–2·1
SULPHUR %	0·06	0·07	0·08	0·05	0·08	0·07	0·06
PHOSPHORUS %	0·6–0·7	0·6–0·7	0·6–0·7	0·4–0·5	0·25	0·25	0·25
MANGANESE %	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5
TOTAL CARBON %	2·7–3·0				2·8–3·1		

In addition to the above other grades of Dale Refined Iron can be supplied to meet more exacting demands which call for alloy additions and special processing.

STANTON *Dale Refined* PIG IRON

THE STANTON IRONWORKS COMPANY LIMITED NEAR NOTTINGHAM

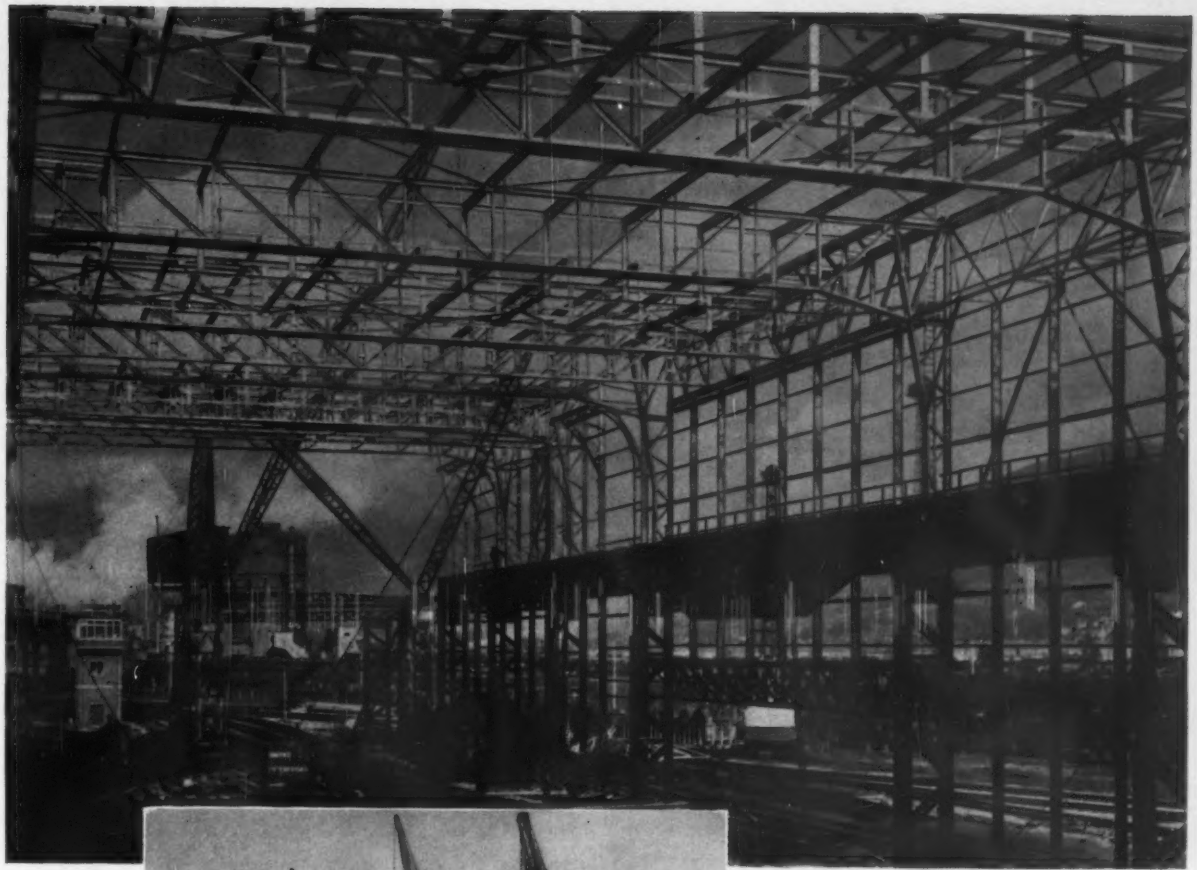
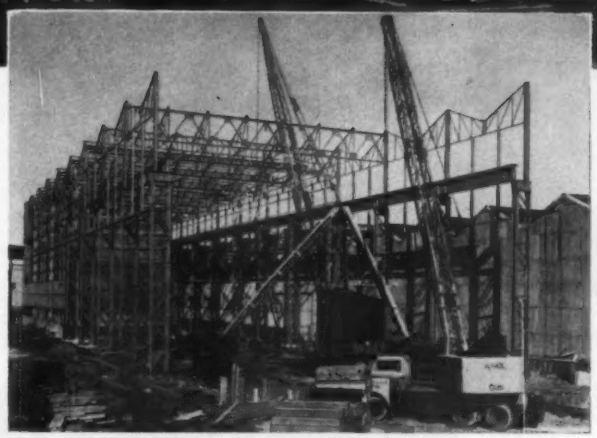


Photo: Steel Company of Wales.



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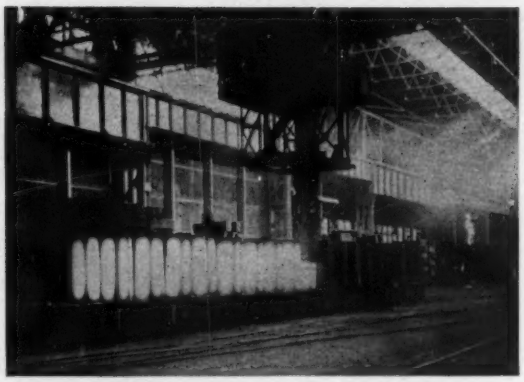
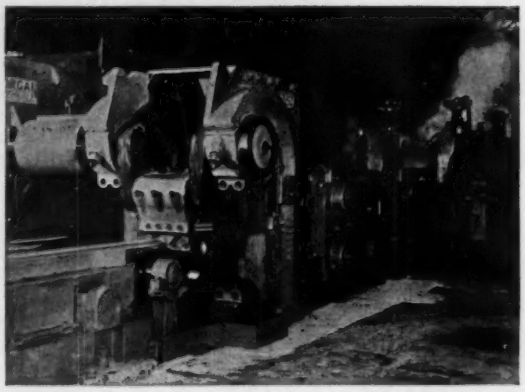


STRIPPING BAY



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BILLETS	2″, 2¼″, 2½″, 3″, 3½″ & 4″
SLABS	5″ TO 16″ WIDE X 1¾″ TO 2½″ THICK
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RODS IN 500LB. COILS
(I/D 28″ O/D 36″)

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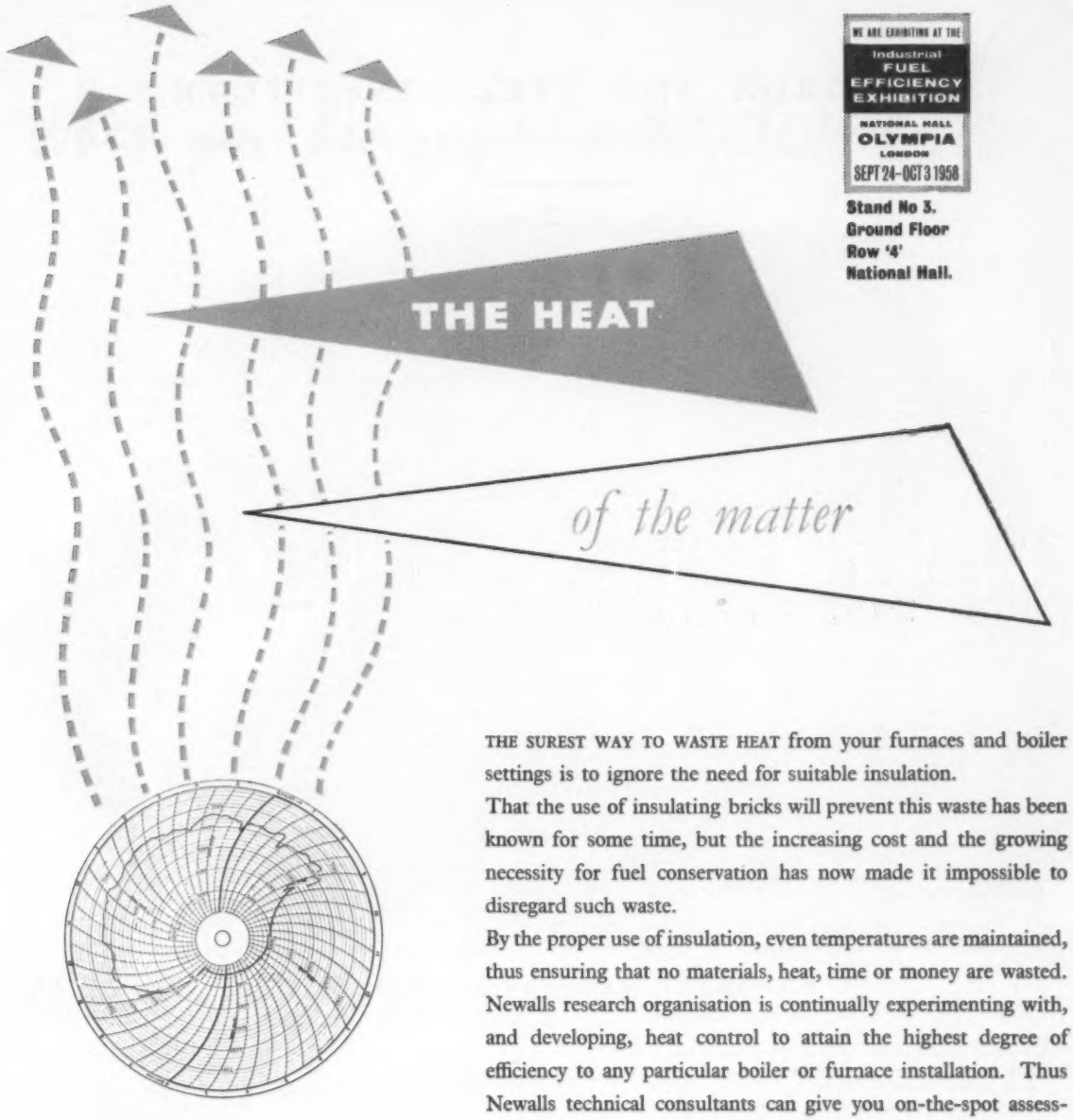

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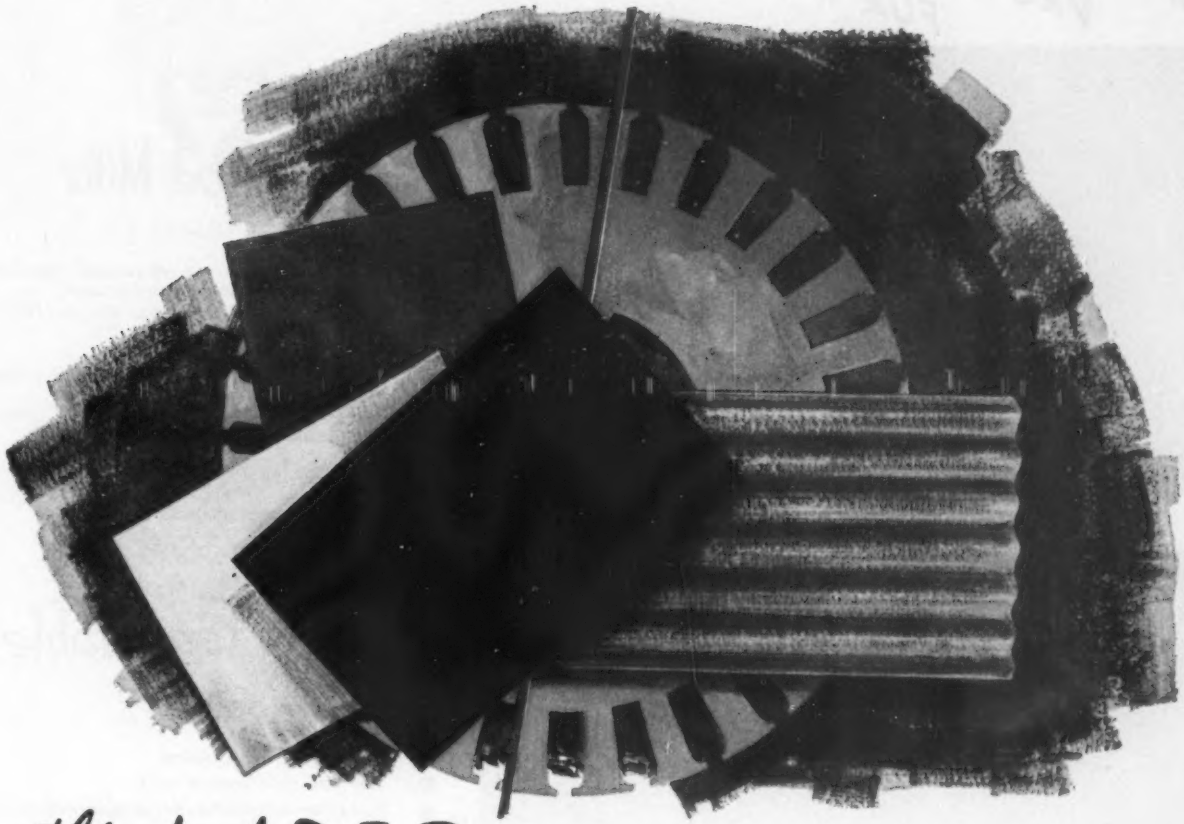

think of R·T·B

The illustration, with some latitude, serves as a reminder of R T B tinplate, black sheets and specially coated sheets—together with a corrugated 'Speltafast' galvanized sheet and, behind them all, a large electrical lamination, made by R T B from one of their special steels.

Our history comprises a long sequence of developments which have proved of far-reaching importance to industry and to the general public. In steel making, in the production of tinplate, sheet steel and strip, in the manufacture of special steels and laminations for the electrical industry, and specially coated sheets, the name of R T B has always been associated with leadership.

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PATENTED Rod Mills

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Fine Crushed Coke

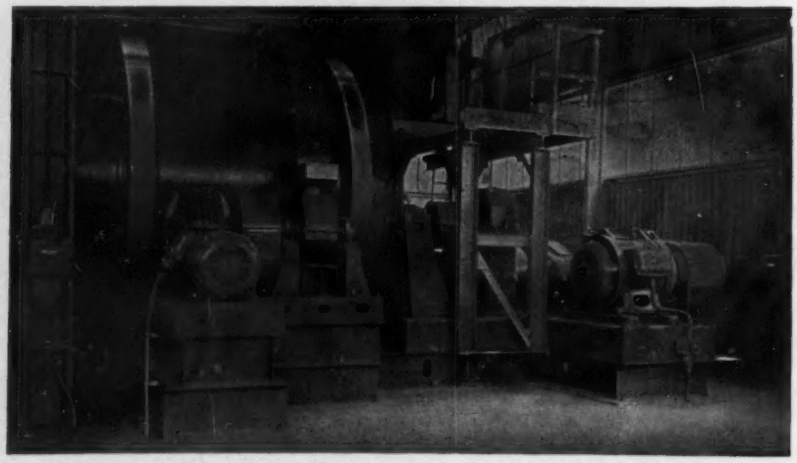
- Uniformly graded coke of constant fineness so essential for making first class sinter.
- Crushes breeze containing up to 16% of moisture.
- No predrying necessary.
- Reliable operation with lowest overall maintenance costs.
- Proved by continuous service since 1938 in seven leading British Steelworks.

A battery of nine Newells Feed Tables in operation at a Steelworks Sinter Plant.

HEAVY DUTY Feed Tables

for handling
Ore & Sinter Fines, Coke, Mill Scale and Flue Dust

- Very reliable in operation.
- Very low maintenance costs.
- Proved by continuous operation in British Steelworks since 1938.
- We have supplied 37 Feed Tables for different sinter plants at Messrs. Appleby-Frodingham Steel Company.



One of 12 Newells patented Mixers in operation at Appleby-Frodingham Steelworks.

PATENTED COMBINED Drum and Paddle Mixers

for mixing
Ore & Sinter Fines, Coke, Mill Scale, Flue Dust and Water

- Intensive, thorough and uniform mixing of solids and water unobtainable by any other machine.
- Efficient mixing is a primary necessity for the manufacture of first class sinter.
- Made in units up to 300 tons per hour continuous capacity.
- Proved by continuous operation in British Steelworks since 1938.

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Vol. 190 Part 1

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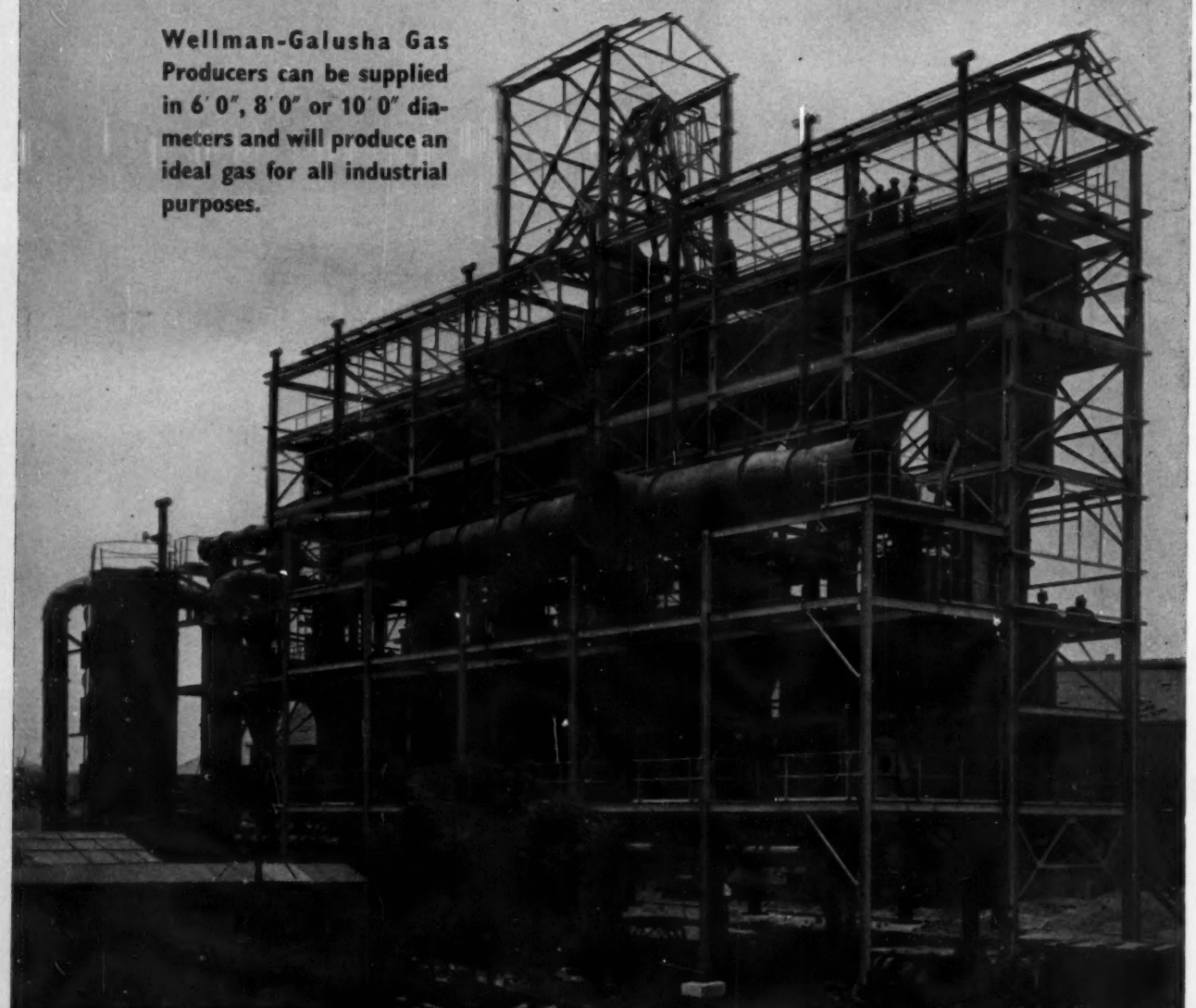

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R. C. BAKER, A.Met., F.I.M.

ROBERT CECIL BAKER was educated at Uppingham School and at Sheffield University and was awarded an associateship in ferrous metallurgy in 1937.

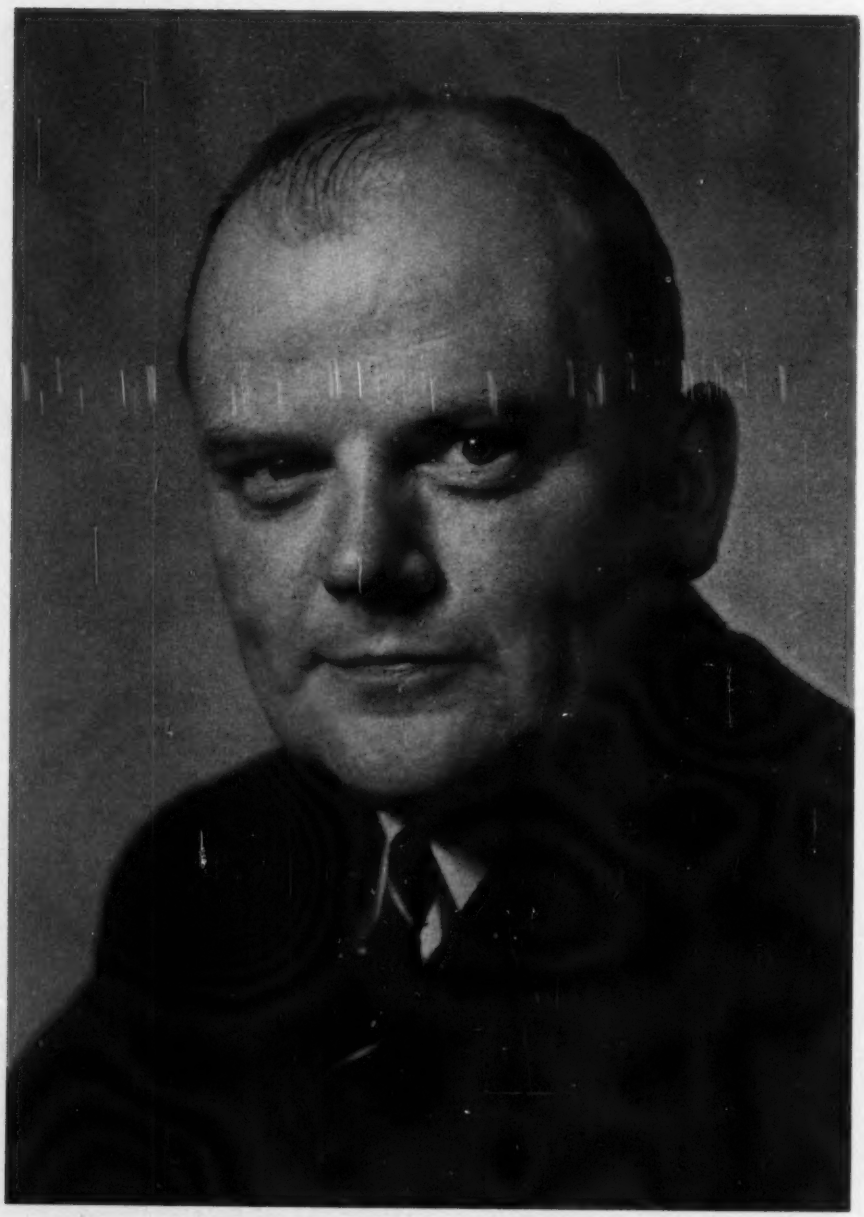
He served for a year as a trainee in the research and steelmaking departments of the English Steel Corporation then was appointed assistant melting-shop manager at the Kilnhurst works of John Baker and Bessemer Ltd.

In 1945 he succeeded his father, Mr. Sydney E. Baker, as steelmaker at John Baker and Bessemer Ltd., and became responsible for the production of acid and basic steel, and for the company's chemical and metallurgical laboratories. Mr. Baker is also in charge of steel-plant development and his company was one of the first to install automatic roof-temperature control on an open-hearth furnace.

He was appointed a director of John Baker and Bessemer Ltd. in 1951.

Mr. Baker's varied interests within the iron and steel industry are shown in his service on committees of the British Iron and Steel Research Association and the British Coal Utilisation Research Association. He has also published a number of papers on instrumentation in open-hearth furnaces.

Mr. Baker is a fellow of the Institution of Metallurgists and a member of the A.I.M.M.E., the Sheffield Metallurgical Association, and the Sheffield Society of Engineers and Metallurgists. He joined The Iron and Steel Institute in 1946, and this year, as President of the Sheffield Metallurgical Association, he serves as an Honorary Member of the Council of the Institute during his term of office.



R. C. Baker, A.Met., F.I.M.
Honorary Member of Council, 1958

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RESEARCH AND PRACTICE

Metallurgy · Plant Operation · Research

The Use of Oxygen in a Modified Tilting Furnace

By A. Jackson,

Assoc. Met., F.I.M., C.G.I.A.

SYNOPSIS

The paper describes experiments on bath lancing with oxygen during melting using, first, hand and, subsequently, mechanically operated lances. It then indicates developments using a modified design of a 300-ton tilting furnace, full instrumentation, waste-heat boiler, and fume-cleaning plant. Results of five months' operation are given and the problems requiring further attention are recorded. The work of dismantling and reconstruction of the furnace to a close time schedule is briefly recorded. The results show increased production and a very considerable reduction in fuel usage. 1604

THE FIRST SECTION of the paper gives a general description of the experiments and the process subsequently developed. It describes the reasons behind the modifications to the furnace. The code name 'Ajax' is used to distinguish the modified furnace and process from normal furnaces and practice.

Oxygen was first applied on Appleby Melting Shop during melting in an effort to further speed up the whole process in 1950. In these experiments the furnace was charged according to standard practice, less a few tons of oxides, and lances were inserted into the bath immediately the addition of molten mixer metal was complete.

Two 1-in. steel pipe lances suspended from supports attached to the furnace were inserted through holes in No. 2 and 4 doors (*see* Fig. 1) and fed in by hand as required. A plant for the evaporation of liquid oxygen was installed for the trials, which continued steadily for several months, giving sufficient information to acquire a good knowledge of the possibilities of this method of application of oxygen.

The furnace operation was characterized by:

(*a*) The evolution of intense brown fumes.

(*b*) Boiling reactions of greater activity than those normal to tilting practice, which caused additional overflow of foamy slag from the bath. This slag was 'thrown off' at other than normal 'slag off' times, and was often higher in iron than normal practice.

(*c*) Lower yield, owing to the reduced requirement of oxides and increased iron loss in the slag.

(*d*) A marked increase in the rate of wear of refractories in ports, uptakes, and roof (silica). The roof wear warrants special comment; instead of the normal method of 'burning,' resulting in the formation of long visible icicles, the roof in this case 'ran like raindrops,' which were only visible at certain times and from appropriate angles, against the dark background of the air ports. This method of wear left no visible trace on the roof after each charge, but after a number of charges the rapid loss of roof thickness became evident.

(*e*) Increased output, which was difficult to estimate because the experiments could not be made on a continuous series of charges. Furthermore it is well known that charges apparently identical in every observable way can vary widely in output rate. After making all possible adjustments, it was estimated that the production increase was 10–12%.

(*f*) The nuisance caused by the tangle of tubes and pipes across the stage, which prevented passage of the charging machines.

As a result of a small number of minor accidents in the oxygen system, the men contended its use in this way was hazardous and a potential danger. In spite of many months spent in trying to 'increase its safety,' the experiments were abandoned.

They could be summed up as follows:

(1) Owing to the increased rate of wear on the furnace, decreased availability would reduce the production gain to 10% maximum

(2) Cost was increased by decreased yield and a small increase in the labour used around the furnace

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Fig. 1—Hand lances in use

(3) At the oxygen prices then prevailing, the ingot cost was above standard practice
(4) If the mills could roll more steel, as an expedient it was advantageous to have the extra ingot production, even at the higher cost.

The use of oxygen for combustion at certain times during charging arose from these experiments and became standard practice, which is still used today.

A few years after these trials, developments in the use of oxygen for steelmaking were taking place in several parts of Europe and the author was given the privilege, by Professor Bo Kalling and Dr. R. Graef, on two occasions of studying the Kaldo and Rotor processes in detail. Their results were reviewed in the light of the Company's need to increase ingot production in late 1959 by the output of one large tilting furnace. They indicated that, although the tilting process is probably the nearest in terms of production costs to these oxygen processes, the latter were cheaper producers, and so it was wrong to build a further tilting furnace. On the other hand, it appeared that, if either the Rotor or Kaldo vessels were used, they should have a capacity of 100 tons. Owing to their high output rate, the expected production would be very much greater than required, and so the introduction of this kind of process would render certain existing steelmaking plant redundant. Investigation indicated that the necessary return on capital invested in this way could not be definitely seen, nor did the Company wish to invest the large capital sums necessary to replace plant still producing more economically than most.

It was decided not to build the additional tilting furnace and to maintain a continuing interest in the new oxygen processes, against the time when a larger increase in production became necessary. Meanwhile, the extra steel had to be made and it was decided to work in two fields, by introducing the all-basic furnace, and by the further application of oxygen to existing plant and practice. The latter development could utilize oxygen from a tonnage oxygen plant being built in the district.

The All-basic Furnace

For a number of years, the United Steel Companies Ltd. have been experimenting at Steel Peech and Tozer on behalf of its branches on the all-basic furnace, using conventional types of roof suspension. In preparation for its possible eventual application to Appleby-Frodingham, a project was started in 1951 to develop all-basic furnace ends.

As a result of the author seeing basic roofs in use on large fixed furnaces in Russia in October, 1955, it was decided to experiment with their use at Appleby-Frodingham on tilters. No suspension was used, but the main roof trusses were strengthened and apparatus was made to hold down the roof at several points across the furnace on lines parallel to the long axis of the hearth.

Eight rings were first tried on a silica roof and, as they were reasonably successful, full roof trials followed on the same furnace. All seven 300–350-ton furnaces have now basic roofs, sprung from normal fixed skewbacks, and held down in operation as described. Lives up to 17 weeks are being achieved with British-made bricks. Production gain is not less than 10% and, taking this into account, the break-even life is 12–13 weeks.

APPLICATION OF OXYGEN

The successful application of the basic roof and the availability of tonnage oxygen within a year immediately turned thoughts again to the use of oxygen for speeding up the working of the charge in all its stages.

The melters were called together, the implications of the new oxygen processes were conveyed to them, and their co-operation in the use of oxygen was asked for. They agreed, and their co-operation has since been of the highest order and a great aid to subsequent developments.

Lancing trials began on several silica furnaces, but, as *B* furnace was the first to use a basic roof, they soon became concentrated on this furnace. At this time oxygen was available only from a satellite evaporator and to accumulate sufficient for three or four charges a week, to be worked on days if possible, was quite a feat of organization.

Door Lancing

The first trials again used two 1-in. steel-pipe lances through holes in No. 2 and 4 doors, but they differed from the 1950 trials in these respects:

(1) The charge was below full furnace capacity to allow for sponging. It also contained a high percentage of hot metal
(2) Gas was ' shut off ' during lancing and the draught lowered to maintain a good positive pressure in the furnace
(3) During lancing, the oxygen supply for combustion was turned on when necessary to consume the CO evolved from bath lancing. In fact, this was rather wasteful of oxygen because, even with the air supply completely cut off, the infiltrated air was generally more than sufficient to consume all the gas evolved from the bath.

About a dozen charges were worked in this way, and useful production gains were recorded and fuel savings achieved. The process was impracticable, however, as the rubber flexes impeded the passage of the ground chargers, and handling the lances, even with suspended hangers, was an unsatisfactory and labour-consuming job (details are given later).

Mechanically Operated Water-cooled Lances

It was not practicable to insert a lance through the roof of these tilting furnaces, and the only possibility

was through the port ends, as shown in Fig. 5. The lances were therefore made retractable. They had a number of weaknesses, arising in particular from the need to adapt them to an operating furnace to avoid several weeks waiting until it was due for repairs; the basic roof on at that time lasted 20 weeks.

Lance manufacture, especially making and welding the copper ends, caused plenty of difficulties which were largely overcome. Additional water pumps were installed to boost the volume through the lances; this worked well unless they were brought close to the metal, when temperature and erosion soon caused leakage. Various orifice types and sizes were tried to give indications of the effect of varying velocities.

Lances were withdrawn except when ' blowing,' and reversal, which was a little cumbersome, took place at intervals of ½–1 h. The slow rate did not appear to have much effect on the temperature of the regenerators, as the incoming air was ' shut off ' completely and the outgoing draught was low. Much fume escaped through the openings at the furnace end and the doors, and the draught used had to be adjusted mainly to avoid filling the shop with fume and obscuring the lighting, especially at night.

PRELIMINARY EXPERIMENTS

These trials gave some very high output rates, peaking at nearly three times normal practice, and the detailed results showed the process to have such potentialities that its further development was imperative. Time was also a factor, as additional steel had to be available for mill requirements when developments already started became operational.

A decision had therefore to be taken on the future development of this process less than halfway through the tests. It was decided to proceed with furnace modification and reconstruction. Only after this decision had been made did the serious effect of the process on roof life become apparent, and this only when sufficient oxygen became available to run a series of successive charges.

In the tests all oxygen was received in liquid form and, owing to the small capacity of the evaporators, a tight schedule of tanker arrival and discharge had to be made. This, coupled with furnace difficulties, meant that seldom were more than three trials possible per week. Eventually, by excellent co-operation with the British Oxygen Co., Ltd., it became possible to work a short series of charges in succession; it was then discovered that, with certain British basic bricks, the roof needed patching in as few as 14 charges at the worst, or just over 5 days' continuous working. This was a very considerable surprise, but it indicated that the furnace was like any other, i.e. it could give high production if allowed to ' burn down ' very quickly.

From roof-temperature measurements described in a later section, it was found that the roof temperature reached extremely high figures during lancing, if theoretical air was used for consuming the evolved CO. The use of high percentages of excess air reduced this temperature but obviously increased the heat loss from the furnace hearth.

Two small steam jets were inserted in each port end. They were reversed with the furnace and served to direct the air stream along the bath surface. This materially reduced the roof temperature and allowed an air volume much closer to theoretical to be used. This arrangement is probably the most significant contribution to improved roof life yet achieved.

Fig. 2—General view of the furnace

The results of the tests completed when the decision was made to develop the process further were:

(1) High rates of production were possible, but roof life would be much shorter than normal open-hearth practice
(2) As only single charges were worked, because of oxygen availability, the slag left on from the previous normal charge helped to increase the production of the oxygen-blown charge
(3) Considerable savings in fuel were possible and gave a small cost surplus, even after deducting the cost of tonnage oxygen and yield loss
(4) An ordinary open-hearth furnace could not be adapted because the dust blocked the checkers in a very few days, and they could not be kept clean by lancing
(5) The dust evolution from the stack was intolerable and gas cleaning therefore inevitable
(6) The infiltration in even a good open-hearth furnace would make a gas cleaner of upwards of 2×10^6 ft³/h at N.T.P. necessary, even if controlled cold-air infiltration was not to be used to ' cool ' the waste gases before cleaning
(7) Foaming was sometimes very severe and unpredictable, and so the charge size was reduced to 210 tons in a 300–350-ton furnace.

The possible gains indicated by these results, especially in production, could not be ignored. On the other hand, for several reasons the process could not be satisfactorily operated in a normal furnace.

REDESIGNED FURNACE FOR OXYGEN PROCESS

Examination of the problem indicated the necessity for very considerable changes in furnace design and structure; if these were to give an efficient oxygen process, they could not at the same time give a furnace which could be immediately changed to normal O.H. practice and be fully efficient.

As success could not be assured and further knowledge could only be acquired by full-scale trials, the decision to dismantle the furnace and reconstruct it for oxygen blowing was not an easy one to take. At that time steel supply was only just sufficient to keep the plant going with a stock high enough to allow not

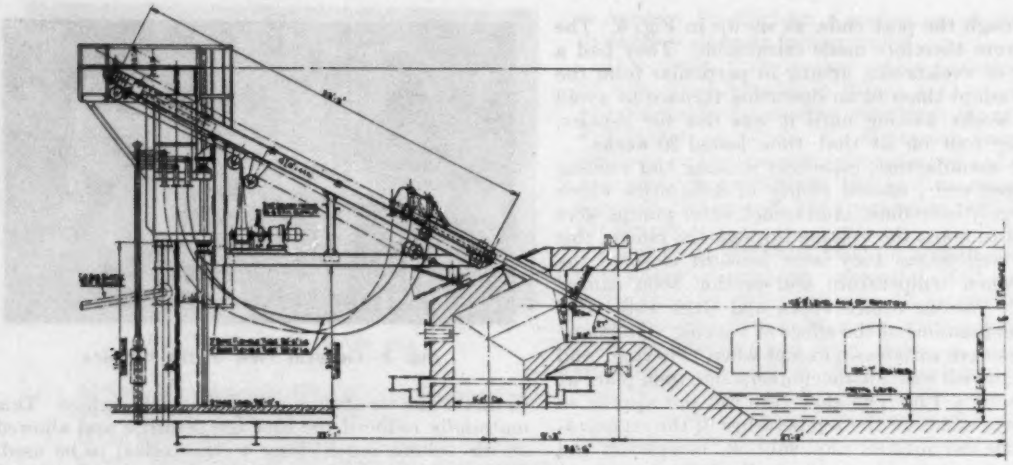


Fig. 3—Cross-section, showing lance

more than an extra 21 days above a normal repair for complete removal and replacement of ports, uptakes, slag pockets, regenerators, valves, and part of the flues (including all steelwork and much concrete). This exercise, which was first planned and then subsequently achieved in 27 days from 'gas out' to 'gas in,' is described later.

The factors upon which the furnace was redesigned were interlocking and are therefore difficult to describe in logical sequence. It is probably simplest to commence description from the chimney end (*see* Figs. 2, 3, and 4).

Here the first problem was gas cleaning. A firetube waste-heat boiler was already on order before this process was designed, and installation was continued. Various gas-cleaning methods were considered but the methods considered were limited by three factors: cool gases would be available from the waste-heat boiler; a dry cleaning method was desirable because of the local water-supply position; and the plant least expensive in capital cost likely to do the required work should be chosen, having in mind also the possibility of oxygen-blowing being unsuccessful.

After consideration, a bag-filter plant was decided upon. This was definitely made to the minimum theoretical capacity, which is far below that for any furnace of comparable production potential.

In order to minimize the gaseous volume to be cleaned, the reconstructed portion of the furnace was designed so as to have no infiltration whatever. The whole structure of ports, uptakes, slag pockets, regenerators, and flues, to the junction of the main stack flue in the valve arch, was to be completely encased in steel, with appropriate flexible packing joints at every junction and around every lid, designed as a cleaning or inspection opening.

Consideration was given to the possibility of having neither slag pockets nor regenerators but merely a flue to which large quantities of cold air were admitted at the junction of the tilting hearth and the port end, thus keeping all fume as dust throughout the system, and having a very large gas-cleaning plant. This idea also had logic if the furnace was to rely on oxygen for both lancing and consuming the evolved CO.

The decision in favour of regenerators and slag pockets was made for the following reasons:

(1) If the volume of products of combustion is minimized by excluding all possible air inleakage, slag pockets will be necessary
(2) A certain volume of oxygen from hot air can be used to replace cold oxygen, for consuming evolved CO without loss of thermal efficiency
(3) If the flame temperature in the vicinity of the point of impact of the lance is unduly high, the addition of air or oxygenated air instead of pure oxygen can be used to lower the intensity and to spread the evolved heat over a larger area of the hearth
(4) The furnace will finish the charge, especially when making carbon steel, under a normal fuel flame. At this time hot air can be used with advantage for giving the required flame length
(5) Regeneration will increase the thermal efficiency of the furnace and also 'even out' temperature fluctuations at the boiler.

The decision to use regenerators having been taken, provision had to be made for easy cleaning; they were therefore made small so that they could be blown relatively easily and quickly by compressed-air lances used at frequent intervals.

The height of the checker filling is similar to that of the normal open-hearth furnace, but the maximum gaseous flow rate is much nearer that of a blast-furnace stove than an open-hearth regenerator. A further point in favour of the small cross-sectional area of the regenerator arises from the intention to use oxygenated air if necessary to assist combustion and so minimize the waste-gas volume. The latter is quite low during the lancing period, which occupies the major portion of the charge time.

The offtake from the furnace hearth was reduced very considerably in area for four principal reasons:

(1) To lift the furnace end bank as high as possible to minimize slag overflow when sponging
(2) To minimize the overall weight of the offtake and uptakes so that they can be lifted off by crane and quickly interchanged
(3) To minimize the cost of relining, as they are of all-basic refractory
(4) Because the gas volume leaving the hearth for most of the operating time is much below that of the normal open-hearth furnace.

When these dimensions had been chosen, it became possible to have two separate slag pocket and regenerator systems at each end of the furnace, without taking up any more space than that occupied by normal regenerators. This means that all below-stage repairs take place with the furnace in operation (i.e. a general repair takes only the time required to rebuild the hearth section of the furnace) and that slag pockets can be allowed to cool before repairs start, so that the men can work in good conditions. Furthermore, overmanning and shift work repairs should be unnecessary, repairs being conducted by a very small group of men working regularly on days.

Next the type of refractories to be used were considered. It was believed that the temperature of the gases leaving the hearth would be very high, and so an all-basic lining was used for ports, uptakes, slag pockets, and the upper half of regenerator chambers and checkers.

For simplicity of construction and strength of design and to minimize the volume of basic brickwork required, slag pockets and regenerator chambers were made cylindrical in cross-section. To conserve heat and protect the steel structure, insulation was used from the furnace hearth to the chimney flue. It consists of about 1 in. of Dextramite slabs on the steel shell, then 4½ in. of hard insulating firebrick, with generally 13½ in. of basic end arch bricks as the working lining.

To ensure tightness at the junction of tilting hearth and port, machine-faced chills are used. The port is on wheels with a water-seal connection to the uptake. Electrically controlled compressed-air cylinders are used to ensure the best possible contact between these chills. The waste-gas reversal valves are standard hot-blast valves as used on the ironworks stoves.

The oxygen lance passes through the end of the furnace as shown in Fig. 3 and is withdrawn at each reversal. It can be changed in 35 min.

Another problem was that of fuel burners. Had these been inserted through the port ends the opening would have had to be larger and, to allow for port-end movement, there would have been many more trailing flexes. To overcome this, the coke-oven gas burners are inserted in each corner of the tilting portion of the hearth. They can use oxygen to assist combustion when required; this enters the furnace in the same water-cooled burner through two holes just below each gas inlet.

This placing is not very efficient for rapid melting, but is quite adequate for holding the bath temperature when finishing refining, burning in dolomite, or heating up scrap. The thermal input is low by design and, without oxygen, the furnace would produce steel at probably no more than 10–12 tons/h compared with 2½–3 times this quantity when the furnace is used for its designed purpose.

INSTRUMENTATION AND CONTROLS

The furnace has a very comprehensive control and instrument panel and, as successful operation is based on rapid manipulation, all valves are operated by electric pushbuttons from this central control. In addition there are ON–OFF valves which cut off gas, air, and oxygen quickly, but leave the original settings unchanged, so that almost instantaneous reversion to former operating conditions is possible.

The controls enable oxygen to be used through the water-cooled lances, through the coke-oven gas burners for combustion of fuel gas or evolved CO, or to add oxygen to the air through the regenerators—a possibility because of freedom from infiltration.

Furnace pressure is controlled automatically but has rapid manipulation for use when sampling or feeding. Coke-oven gas volume is coupled to roof temperature.

Oxygen volume is controlled by small handwheels on the panel, which operate air-assisted valves. A more detailed description of the electrical control apparatus and instrumentation is given later.

FURNACE OPERATING CONDITIONS

(1) Roof control temperature 1700° C (can only be measured when fuel firing)

(2) Furnace pressure: + 0·09 in. w.g.

(3) Thermocouple at top of regenerators has audible warning device to ensure 1250° C is not exceeded (minimum 890° C)

(4) Chimney flue temperature at entrance to waste-heat boiler: 600° C. (*Note*: gaseous volume is lower than that of normal O.H. furnace)

(5) Temperature leaving waste-heat boiler: 225° C

(6) Steam generation (average): 10,000 lb/h

(7) Fuel and oxygen consumption is given in detail in later sections.

Principally in order to check refractory wear, especially in ports and uptakes, a survey by contact pyrometer is taken weekly. When failure appears possible, provision is made to spray the hot spot with water so that changing can take place at a convenient time. Typical normal surface temperatures are:

Ports (offtakes)	130° C
Uptakes	145° C
Slag pockets (upper half)	125° C
Regenerators (top)	120° C
,, (bottom)	115° C

The average uptake temperature is higher than the port end because the rate of wear is greater in certain places.

SUMMARY

To date the operations can be broadly summarized as follows:

(1) Output has definitely increased compared with the normal furnaces at Appleby-Frodingham.

(2) There is a slight reduction in ingot cost resulting from important gains in fuel, but this is counteracted by important losses from lower yield and the high percentage of hot metal, plus the cost of oxygen.

(3) Losses of iron in the slag are much higher than normal practice; no methods of reducing them have yet been discovered without slowing down the process, which gives a greater increase in cost than the saving in iron is worth.

(4) Roof life is a costly and serious problem but, owing to the low ' below stage ' cost, the overall refractory cost per ton appears to be no more than present practice.

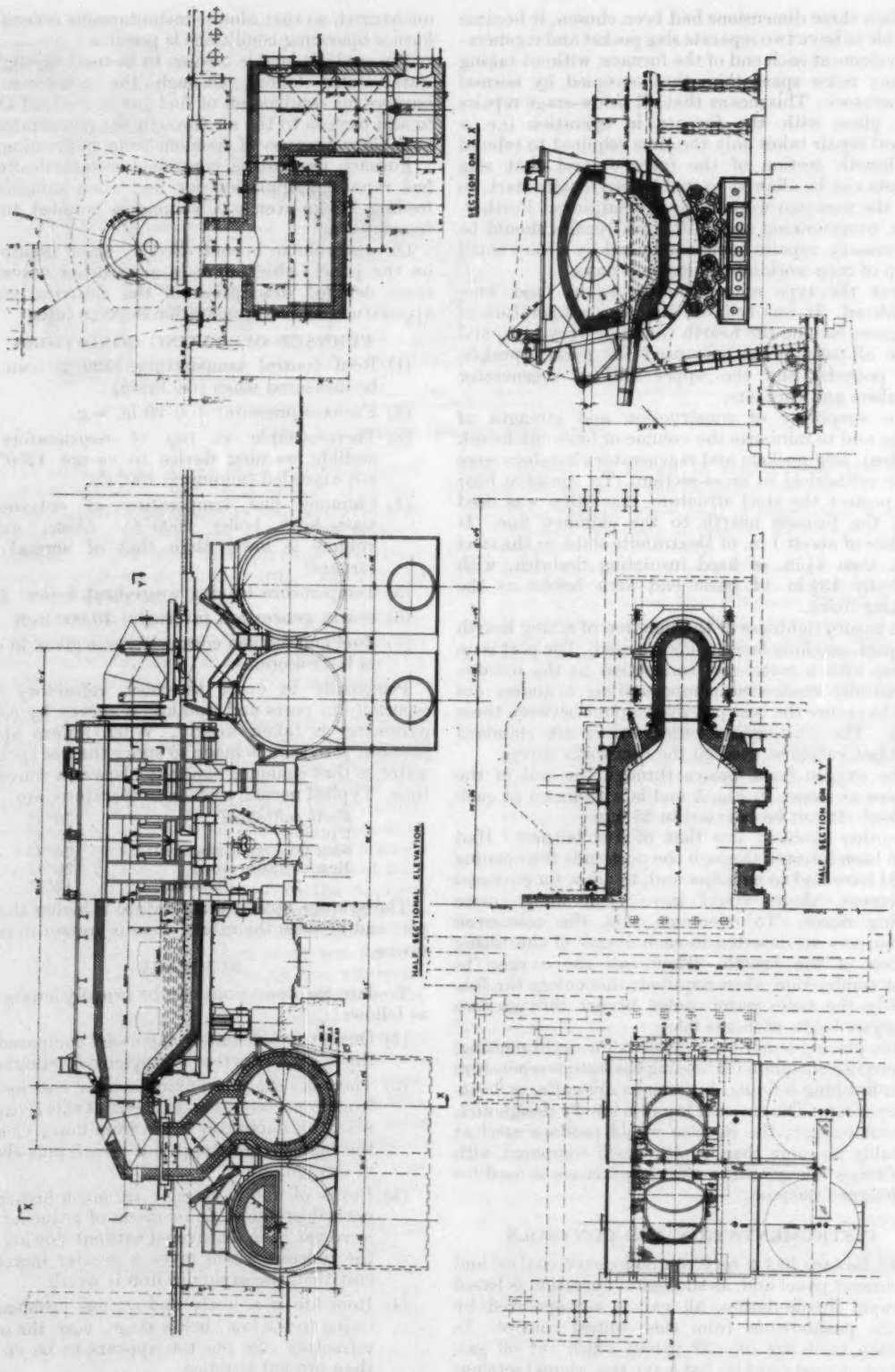


Fig. 4—Redesigned furnace

(5) The problems of lance life and the best gaseous velocity when lancing have not yet been solved.

The position can be summed up broadly by saying that an important increase in ingot output, required for the mill extensions, has been obtained at an ingot cost no greater than normal practice, without expending significant capital on new furnaces. Work remains to be done to increase metallic yield, improve roof life, and design suitable lances. It will be surprising if further work on these items does not bring useful cost reductions.

ACKNOWLEDGMENTS

To some the most striking feature of this paper will be the short time between making the basic experiments and giving operating results of the 'Ajax' furnace covering several months. This results from the combined efforts of very many people from design to construction and operation.

The basic work was organized, however, by a small committee, supported individually and collectively by mechanical and electrical engineering, production, and construction departments who followed closely the work of the design department and drawing office. The committee comprised Messrs. A. Jackson (*Chairman*), S. H. Brooks, E. F. Farrington, W. Jackson, H. Jenkinson, R. Johnson, I. M. Kemp, N. H. Turner, and R. Wogin.

Various members of management also had specific tasks, which are described in other sections of the paper. One facet is, however, missing—the Construction Committee under the chairmanship of Mr. J. L. Gaskell (Chief Engineer), which planned all details of the changeover and accomplished it in 27 days from 'gas out' to 'gas in'.

Once the furnace was in operation there was still much to do, men to train, and teething troubles to be overcome. Three members of the managerial Melting Shop staff, Messrs. W. L. Willsher, R. Pidd, and H. Marshall, operated continuous shifts for some months, and they were ably supported by the departmental engineers. The men on the shop also showed great interest in the process and worked hard to overcome problems as they arose and gave the fullest cooperation at all times.

As a result of all these efforts, the technique has developed relatively quickly from the experimental stage to a point when this 'Ajax' furnace has become the largest steel-producing unit on both melting shops.

Bath Lancing Experiments in 1957

By

W. Jackson, A.I.M., R. Johnson, B.Met, A.I.M., and H. Marshall, A.R.T.C.

Experimental work on bath lancing in large tilting furnaces having a silica roof began in 1950. This report, however, records only the experiments carried out in 1957 before a furnace was designed specially to work this oxygen process.

In the first series of experiments the melters used hand lances when they thought it advantageous to speed up the process, and these trials were almost all on furnaces with a silica roof. The results of charges with and without lancing were as follows:

Number of charges	46	44
Charge weight, tons	301·5	321·2
Tap-to-tap time, h	16·15	16·07
Tons/hour	18·65	20·05
Increased production rate, %		7½
Combustion oxygen time, min	63	66
Combustion oxygen volume, ft³	45,400	44,570
Lance oxygen time, min		64
Lance oxygen volume, ft³		40,600
Oxygen used, ft³/ton	150	265

Figure 1 shows hand lances in use.

The next trials were made on a furnace with a basic roof. Hand lances were used much more continuously and combustion oxygen was fed into the furnace through the fuel guns to burn the evolved carbon monoxide in the furnace hearth.

The air fan inlet was closed and the chimney damper lowered to minimize air infiltration. Two steel-tube lances were used, each passing 30,000 ft³/h of oxygen, and upwards of 60,000 ft³/h passed through the fuel guns for combustion.

The results were as follows:

Number of trials	13
Charge weight, tons	204
Tap-to-tap time, h	6·79
Tons/hour	30·12
Combustion oxygen time, h	5·38
Combustion oxygen volume, ft³	332,660
Lance oxygen time, h	3·00
Lance oxygen volume, ft³	115,200
Oxygen used, ft³/ton	2195
Fuel, therms/ton	15·5

The charge size was reduced to 200 tons to minimize foaming, which was considerable in some charges.

Table I

RESULTS FROM SECOND SERIES OF TRIALS WITH HAND LANCES

Total Charge Weight, tons	Scrap Weight, tons	Ingot Weight, tons	Av. Mixer Metal Analysis					Additions, cwt/ton				Tap-to-tap Time, h	Tons Per Hour	Therms Per Ton	Oxygen, ft³/ton	Remarks
			C, %	P, %	Mn, %	Si, %	S, %	Burnt Lime	Rough Lime	Red Ore	Scale					
204	Nil	191	3·15	0·99	0·50	0·32	0·066	0·92	0·91	2·04	0·14	8·1	25·2	18·4	2780	First five trials
200	Nil	196	3·14	0·89	0·43	0·22	0·053	0·59	0·23	1·82	Nil	6·32	31·64	13·9	1818	Second five trials
213	13	192	3·12	1·17	0·48	0·28	0·055	0·85	Nil	1·91	Nil	6·05	35·58	12·9	1826	Last three trials

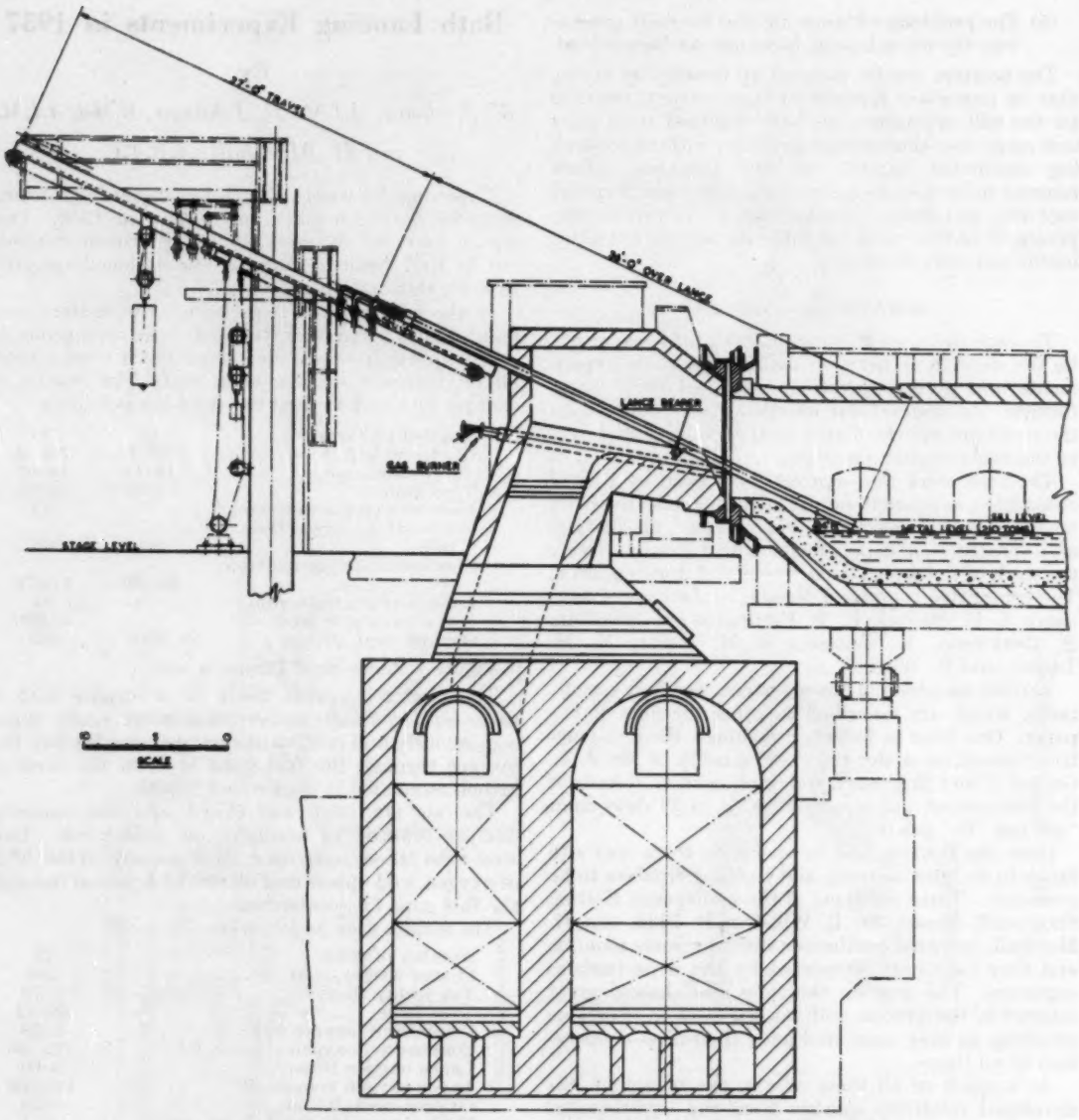


Fig. 5—General arrangement of lance gear; lance shown in blowing position

The thirteen charges were made over a period of seven weeks. It was not possible to run consecutive charges because of difficulties in oxygen supply, which at this time was entirely from a satellite plant, modified from its original evaporation rate of 60,000 ft³/h to give 100,000 ft³/h, and later 120,000 ft³/h.

Table I shows the results given above, broken down into groups to show progressive development.

No evidence of serious refractory damage was apparent in this intermittent series of experiments.

These trials indicated the possibilities of the process, but it was also evident that trailing oxygen flexes on the charging stage could not be tolerated on several furnaces on a busy melting shop. Thus water-cooled lances, to be inserted through the furnace end, were designed as shown in Fig. 5.

Twelve trials were carried out between the 17th and 21st week of the furnace life, and the furnace then came off for repair. Further experiments continued as occasion presented itself during subsequent campaigns, and a total of 61 charges were made; the results were as follows:

Number of trials	61
Total charge weight, tons	220
Ingot weight, tons	202
Tap-to-tap time, h	5·81
Tons/hour	37·88
Fuel consumption, therms/ton	11·0
Oxygen consumption, ft³/ton	1520

During these trials the furnace was usually charged with 10 tons of scrap, 12 tons of Brazilian ore, and 1·7 tons of burnt lime, followed as quickly as possible by 200 tons of mixer metal. While these

materials were being charged, the furnace was fired as an ordinary tilting furnace using coke-oven gas and pitch-creosote, with air through the checkers. As soon as the first ladle of metal was charged the air fan was stopped and the damper was lowered, and oxygen blowing started through the lances using 60,000 ft³ of oxygen per hour. Oxygen to burn the evolved CO was put on through the ordinary furnace burners.

After lancing for approximately 1 h, a sample was taken and the slag was run off. Depending upon the analysis of this sample, the volume of oxygen and the weight of ore to reduce the carbon to the desired level for tapping were calculated and thermally balanced. Lime was added in sufficient quantity after slag-off to ensure the phosphorus and sulphur were low enough at tapping.

It should be mentioned at this stage that the small quantity of burnt lime charged for 200 tons of metal was the result of leaving slag on from the previous normal tilting-furnace charge. When the bath reached the desired carbon content (about 0·30% above specification), lancing ceased and the furnace went back to normal air, gas, and pitch-creosote firing to prepare for tapping.

The furnace proved much easier to operate on water-cooled mechanical lances than on the hand lances inserted through the furnace doors. It was possible to keep oxygen on for much longer periods and also to use the higher flow rates.

The following average of the initial 42 charges indicates a very impressive tons/hour with very low fuel and oxygen consumption:

Number of trials	42
Total charge weight, tons	219·4
Ingot weight, tons	203·0
Tap-to-tap time, h	5·25
Tons/hour	41·73
Fuel consumption, therms/ton	9·5
Oxygen consumption, ft³/ton	1405

Certain mechanical difficulties were experienced in the operation of the lances on the inclined slides, but little trouble was experienced at this stage with the water-cooled lances themselves, despite the fact that they had to be positioned before a charge commenced so that the lance nozzle was resting on a water-cooled bearer which passed through the furnace port end as shown in Fig. 5.

At this time it became obvious, when a greater rate of experimentation was being attained, that very serious refractory damage was being done to the roof, and subsequent work was carried out with a view to finding the optimum operating conditions. This necessitated a reversion to a reduced rate of operation. At this stage of the experiment it also became obvious that the productivity of the furnace was influenced by the quality of the mixer iron (in the same way as for normal open-hearth operation), and by the rate of oxygen injection.

The slag irons at ' slag off ' appear somewhat higher with mechanical lancing than with hand lancing, and the lime content is lower. No method of control of the slag iron to give a low figure has yet been devised. The P_2O_5 content of the slag at melting is high, and will have a high value as a fertilizer, since no spar or bauxite is used to flux the slag.

Refractory Wear using Mechanical Water-cooled Lances through the Port Ends

In the initial trials using hand lancing through the doors no apparent serious refractory damage was observed. The charges were carried out over seven weeks on a basic roof that was already ten weeks old.

The first twelve water-cooled lancing experiments were carried out on the same furnace over four weeks, and again no significant refractory damage was noticed.

Sixteen charges were carried out at much shorter intervals on the next furnace campaign with a basic roof, and it now became apparent that refractory damage was severe under fast operating conditions and that less good basic bricks made the difficulties much worse. This was borne out by the failure of a roof after fourteen charges. It was recognized, however, that this roof was of inferior quality.

Many experiments were made to assess the effects of lances with different oxygen velocities and distances from the bath. No substantive conclusions were reached in the number of trials it was possible to carry out in the time available before the furnace was stopped for reconstruction on a new design.

Summary

Despite the difficulties experienced with roof refractories, the trials had shown that high rates of output could be achieved with low fuel consumptions. In view of these experimental results, it was decided to dismantle the experimental oxygen-blowing gear on *B* furnace and proceed with modifications which are described elsewhere in tbis paper.

There was no difference in the steelmaking characteristics of the furnace with mechanically operated lances to that achieved when using hand lances.

The charging metal analysis and the slag-off and refining metal and slag analyses for the whole of the experiments carried out are given below. It is evident that the elimination of phosphorus while the carbon remains high is no problem, as in most instances the phosphorus was below 0·2% whilst the carbon was about 1·0–1·5%.

	13 Charges Hand Lancing	*Initial 42 Charges with Mechanical Water-cooled Lances*	*Final 19 Charges with Variable Lance Positions*
Number of charges	13	42	19
Charging metal analysis, %			
C	3·13	3·21	3·01
P	0·99	1·01	0·91
Mn	0·47	0·47	0·47
Si	0·27	0·28	0·22
S	0·058	0·055	0·050
Analyses at slag-off, %			
Metal: C	1·48	1·47	1·58
P	0·25	0·16	0·17
Mn	0·18	0·12	0·10
S	0·053	0·058	0·048
Slag:			
Total Fe	11·5	14·6	22·0
S	0·138	0·091	0·068
MgO	9·84	10·80	9·24
SiO_2	7·0	7·1	7·1
CaO	42·6	36·8	32·2
P_2O_5	18·17	18·50	16·82

	13 *Charges Hand Lancing*	*Initial* 42 *Charges with Mechanical Water-cooled Lances*	*Final* 19 *Charges with Variable Lance Positions*
Analyses at Tap, %			
Metal: C	0·36	0·34	0·29
P	0·035	0·045	0·046
Mn	0·09	0·08	0·07
S	0·040	0·052	0·041
Slag:			
Total Fe	16·7	19·9	20·2
S	0·198	0·189	0·152
MgO	12·78	10·76	11·91
SiO_2	4·9	5·0	6·2
CaO	42·3	38·4	37·4
P_2O_5	12·70	11·84	11·52

The Operation of the Furnace

By
W. Jackson, A.I.M., R. Johnson, B.Met., A.I.M., and H. Marshall, A.R.T.C.

Warming-up of the furnace began on Monday, 26th January, 1958, using coke-oven gas burners through the charging doors in the usual way, and the first charge was tapped on Friday, 30th January, 1958.

The first few charges worked slowly, using coke-oven gas, pitch-creosote, and some oxygen to give the furnacemen experience with the new controls, and to permit the testing of the mechanical and electrical operation of the furnace.

An analysis of the waste gases indicated that the furnace was very sensitive to conditions of combustion, and excess gas quickly showed itself by the increased quantity of CO in the waste gases. Similarly, a slight excess of air was indicated by an increase in the O_2 content of the waste gases, due to the extremely low air infiltration within the furnace and the valve systems. Accordingly, in operating the furnace care was taken to adjust the air volume (including combustion O_2) to the theoretical quantity required.

OXYGEN STEELMAKING

Full-scale oxygen steelmaking began on Tuesday, 11th February, 13 days after the furnace was initially charged. During this period the furnacemen gained valuable experience in operating the various controls, and the gradual changeover from the use of normal fuels to oxygen was accomplished very satisfactorily. The schedule of operation was based on the practical experience of the earlier trials, and from this point of view the furnacemen were to some extent familiar with the new method of operation.

Before describing what is now standard practice, it is interesting to review some of the major problems experienced in the first three months of operation.

Boiler Fan

After only three days of oxygen steelmaking the furnace was taken off owing to a failure of the waste-heat boiler fan. This necessitated stiffening the fan blades, and no further trouble has been experienced.

Checkers

Initially the top two-thirds of the checkers were bricked with magnesite bricks. However, they quickly became very dirty and, as the top courses cracked, cleaning was inadvisable. The basic bricks have now been replaced with silica, with more satisfactory results, cleaning taking place every three days using a compressed-air lance.

Slag Pockets and Uptakes

Considerable difficulty was experienced in maintaining a stable structure using basic bricks in certain sections of the slag pockets and uptakes; reversion to silica bricks is giving improving results.

Roof

The rapid deterioration of the basic roof was by far the most serious refractory problem, and much experimental work has been done, and is continuing, with a view to improving roof life. Some of the early charges when blowing oxygen at a rate of 60,000 ft³/h indicated that the roof immediately above the lances was wearing at a rate of up to 1–1½ in. per day. It was also apparent that extremely high temperatures were being generated by combustion of the reaction gases, and slag was being splashed in considerable quantity on to the roof.

Experimental work proceeded along the following lines:

(*a*) The measurement of roof temperatures using thermocouples (described in a later section)
(*b*) The effect of varying oxygen flow rates
(*c*) The effect of lance position relative to the metal surface, and the effect of nozzle design
(*d*) The effect of steam jets directed on to the reaction area of the bath.

At this stage, as a result of the experimental work and the experience gained, the furnace was now able to produce at an average working rate per week of 4250 tons. The capacity worked over the last seven weeks amounted to 87%, close to the 90% of the normal open-hearth furnaces at Appleby-Frodingham. Nevertheless, rapid deterioration of the roof is still a problem and experimental work continues.

Although refractory problems arose with the port ends and uptakes, the all-welded construction of these sections permitted external water-cooling, and the furnace was maintained in production without structural damage to the steel casing.

An intermediate campaign now consists of a period of six weeks and this, together with the repair programme, is described below.

An Intermediate Furnace Campaign

Starting with a new 15-in. basic roof and all new sections below stage level, the furnace operation and repair programme is as follows:

(1) Steelmaking continues for three weeks, after which it is necessary to hot-patch the roof over Nos. 2 and 4 doors immediately above the lances. This repair takes 24–40 h from steelmaking to steelmaking, depending upon the amount of brickwork to be renewed.
(2) During this gas-off period the port ends and uptakes can be changed, if necessary, and this will depend upon the amount of slag in the slag pockets, and the deterioration of brickwork in any one section.

A normal life of the port ends and uptakes is 7–8 weeks' steelmaking time, and they are changed accordingly. However, as the complete changeover can be made within 4 h, certain

liberties can be taken in wearing the brickwork out fully and so obtaining a maximum life.

Experiments are also taking place on repairing the uptakes and port ends, using a refractory mix sprayed on by means of a compressed-air gun.

(3) Following the hot repair, the roof is warmed up rapidly at 150° C/h, and charging begins as soon as the roof reaches maximum temperature (1650–1700° C). Steelmaking now continues for a further 2–2½ weeks, when the roof again requires patching.

(4) Gas is taken out and approximately two-thirds of a new roof is installed; on the centre one-third may be left for a further six weeks' operation. During this repair the door jambs of the front lining are also replaced, but the back lining does not require attention, except over long periods of up to six months. Again the furnace may be changed over to the spare system as above.

(5) During the periods of steelmaking, repairs to the spare unit are carried out as necessary to the uptakes and port-ends; the checkers are cleaned, and the slag is removed. In addition, at three-monthly intervals it is also necessary to remove flue dust from the chimney and boiler flues.

The checkers may be expected to have a life of up to six months before renewal of any appreciable quantity of brickwork is necessary.

In each case the flue dusts and slags are salvaged and returned to the Blast Furnace Department for recovery of the iron, which is high, as indicated by the following figures:

Dust ex dust-cleaning plant	65
Slag ex slag chambers	33
Flue dust ex checkers	50

(6) The furnace now operates for a period of 5½–6 weeks (including a hot-roof patch) and then ceases steelmaking for five days, essentially to repair the roof, thus giving a capacity worked of 86–90%.

STEELMAKING OPERATION AND PRACTICE

Steelmaking results have been considered under three headings: the operation and working of the charge; a discussion of the results of the early trials in the new furnace; and a summary of standard operating conditions, detailing production figures and consumption of raw materials.

In this review it must be noted that the results of the previous experimental work influenced the method of operation finally adopted. For example, the rate of production was known to increase with:

(1) Decreasing metalloids in the mixer metal, particularly carbon and phosphorus
(2) Increased oxygen flow rates
(3) Speed of charging, particularly hot metal
(4) Speed of analysis of the bath samples.

There is an optimum distance of the lance nozzle above the surface of the metal which has yet to be determined.

Roof wear increased at high O_2 flow rates and also when the lance nozzle was too near the metal surface. In addition, the lances had a very short life if the nozzle was placed too near the metal. Accordingly, these have been limiting factors in determining the method of operation and the rate of production. Potentially the furnace can be operated at rates in excess of 6000 tons per week using high oxygen inputs, but at present this is not practicable owing to excessive wear on the roof.

Experiments continue with this in mind, but to date the following represents standard practice.

The Working of the Charge

The charge size has been maintained at 210 tons of mixer metal, sufficient with the yield of iron from the oxides charged to give two full 100-ton ladles on tapping. This low charge weight in a 300-ton furnace is found to be the most advantageous to allow for the large volume of slag when foaming or frothing occurs during oxygen lancing.

The method of operation is most easily followed by examining the target schedule issued to the furnaceman. This is for a 210-ton charge, tapped in 7 h at a production rate of 30·0 tons/h.

Typical Charge Data—210-ton Charge

Operation Completed h	min	*Operation*	*Remarks*
0	0	Tapping last ladle of previous charge	Normal fuel and air and some combustion O_2
0	20	Finish measuring bottom, closing taphole, and fettling round	,, ,, ,,
0	40	Finish charging: 7 boxes Brazilian ore 6 boxes burnt lime	,, ,, ,,
1	00	Finish fettling	
1	30	Lance oxygen on after addition of 2nd ladle of hot metal	Fuel off, and air reduced
2	00	Furnace fully charged	
5	00	1st sample and start slag-off	Normal fuel and air
5	30	Finish slag-off	,, ,, ,,
5	45	Finish additions after slag-off. Start lance oxygen	Fuel off and air reduced
6	10	Final adjustments of bath analyses	Normal fuel and air
7	00	Finish tapping	,, ,, ,,

Following the tapping of the last ladle of the previous charge, the bottom is measured (once every 24 h), the taphole is closed, and the back bank is fettled lightly over the taphole.

The oxides are now charged, these being sufficient to stiffen the remaining liquid steel and slag left in the furnace and to permit the fettling of the back and front banks at the slag line. In the early charges, up to 10% of steel scrap was also charged, but this is now omitted, owing to the time taken to charge the material and the subsequent reduction in output. The process can, however, conveniently melt up to 10% of steel scrap if conditions require it.

Table II

PRODUCTIVE DATA AND RESULTS OF VARIOUS GROUPS OF TRIALS, FEBRUARY–MAY 1958

Test group	1	2	3	4	5	6	7	8	9
Number of charges	24	4	10	10	27	14	38	29	40
Scrap weight, tons	10·22	10·65	7·76	1·07	0·01	Nil	0·30	1·21	2·85
Hot metal weight, tons	205·21	215·00	215·50	214·00	216·00	221·60	216·20	226·50	222·50
Total charge weight, tons	215·43	225·65	223·26	215·07	216·01	221·60	216·50	227·71	225·35
Ingot weight, tons	199·00	207·31	208·40	207·14	207·00	213·20	208·00	220·00	209·48
Av. Metal Analysis: C, %	3·12	2·82	2·96	3·10	3·24	3·30	3·22	3·35	3·26
P, %	1·01	0·94	0·96	0·95	0·96	0·99	0·99	1·04	0·98
Mn, %	0·42	0·48	0·36	0·41	0·48	0·42	0·55	0·68	0·46
Si, %	0·24	0·21	0·15	0·28	0·23	0·22	0·24	0·35	0·33
S, %	0·079	0·064	0·072	0·076	0·057	0·042	0·049	0·044	0·075
Tons/hour	25·98	29·52	30·85	25·95	25·00	26·90	28·00	27·02	25·89
Last tap to finish oxides, h	1·15	1·10	0·94	0·96	0·82	0·71	0·71	0·79	1·02
Time to charge, h	2·56	2·61	2·30	2·20	2·34	2·66	2·30	2·42	2·82
Tap-to-tap time, h	8·30	7·64	7·23	8·29	8·65	8·22	7·75	8·45	8·70
Additions: Burnt lime, cwt/ton	0·66	0·68	0·79	0·78	0·70	0·73	0·73	0·79	0·98
Rough lime, ,,	0·10	—	—	0·09	0·04	—	0·12	0·13	0·03
Brazilian ore ,,	1·40	1·17	1·38	1·77	1·74	1·94	2·24	2·19	1·94
Mill scale, ,,	0·01	0·14	—	—	0·01	0·01	—	—	—
Fuel: therms/h	345	415	384	303	288	309	330	291	322
therms/ton	13·3	14·1	12·4	11·7	11·5	11·5	11·8	10·8	12·4
Oxygen: Lance, ft³/ton	997	661	725	850	970	1003	770	1004	988
Combustion, ft³/ton	720	659	421	385	408	378	354	463	705
Total, ft³/ton	1717	1320	1146	1235	1378	1381	1124	1467	1693
Remarks: Average flow rates—lance oxygen during blowing, ft³ O_2/h	60,000	60,000	60,000	40,000	40,000	1 h at 40,000 ft³/h, then at 50,000 ft³/h	40,000	First 1½ h at 40,000 ft³/h, then at 50,000 ft³/h	First 1½ h at 40,000 ft³/h, then at 50,000 ft³/h
	No steam	No steam	With steam jets	With steam jets	With steam jets	With steam jets	With steam jets	With steam jets	With steam jets

Table III

BATH AND SLAG ANALYSES, %

	Oxygen Furnace						Normal O.H. Furnace 12 months ending September, 1957
Test group	1	2	3	4	5	6	
Number of charges	24	4	10	10	27	14	
Analysis at slag-off—Bath:							
C	1·41	1·06	1·15	1·17	1·42	1·17	0·39
S	0·073	0·061	0·069	0·068	0·052	0·042	0·56
P	0·113	0·13	0·10	0·12	0·10	0·12	0·10
Mn	0·10	0·10	0·12	0·10	0·10	0·11	0·17
Slag: Total Fe	16·3	10·9	11·2	12·3	17·1	15·0	7·51
S	0·142	0·063	0·156	0·088	0·092	0·048	0·175
MgO	10·4	8·2	10·2	8·1	8·8	9·2	8·24
SiO_2	6·0	9·2	4·8	5·0	6·0	4·8	9·90
CaO	37·5	40·8	41·2	40·2	38·7	36·2	46·29
P_2O_5	18·7	21·0	21·7	21·3	20·0	18·6	16·65
Cr_2O_3	1·10	0·63	0·97	0·73	0·61	0·66	0·62
Analysis at tapping—Bath:							
C	0·17	0·13	0·15	0·16	0·14	0·11	0·15
S	0·054	0·057	0·056	0·058	0·042	0·038	0·048
P	0·035	0·040	0·036	0·035	0·038	0·037	0·038
Mn	0·07	0·07	0·08	0·07	0·08	0·10	0·12
Slag: Total Fe	16·2	11·4	17·9	15·8	15·2	15·8	13·77
S	0·317	0·274	0·354	0·300	0·230	0·169	0·307
MgO	10·3	7·3	9·8	8·9	8·5	8·0	6·63
SiO_2	4·9	8·8	3·6	5·3	5·2	3·9	7·24
CaO	43·9	49·4	43·6	45·5	44·7	44·7	48·46
P_2O_5	13·3	14·4	12·9	14·5	13·7	14·9	11·90
Cr_2O_3	1·24	1·09	0·94	0·86	0·59	0·87	0·74
Casting-pit Analysis P	0·031	0·030	0·027	0·028	0·029	0·035	0·031
S	0·049	0·055	0·047	0·048	0·040	0·032	0·044
O_2*			0·020				0·022
N_2*			0·004				0·004

* These figures are for a series of random samples not necessarily in periods 1–6

During the final stages of fettling, metal has been ordered from the mixer and is charged almost immediately after fettling is complete. The mixer metal is charged in 65-ton ladles and oxygen lancing starts when the second ladle has been added.

Up to the stage when the oxygen is turned on, the furnace is fired with coke-oven gas and the necessary air plus 15,000 ft³/h of combustion oxygen. This oxygen has the advantage of sharpening the flame and maintaining good heat conditions in the furnace firing normally. Fuel input averages 110,000–130,000 ft³/h of coke-oven gas (550–600 therms/h).

When oxygen lancing starts, the fuel and combustion oxygen are turned off, and the air supply adjusted to the theoretical amount necessary to burn the CO liberated by the O_2, and the reaction from the ore.

In the first instance an approximation is made, and it is assumed that the iron-ore reaction liberates a volume of CO equivalent to one-third of the volume of lance oxygen. The volume of air thus required for complete combustion of the CO liberated is five times four-thirds of the lance oxygen. Final adjustments are made according to the oxygen and CO contents of the waste gases, in an attempt to keep the excess O_2 below 5%. This ensures that the maximum amount of CO gas is burnt in the furnace chamber, thus maintaining the heat efficiency and allowing the maximum amount of iron ore to be charged, which in turn accelerates the rate of production and reduces the amount of gaseous oxygen consumed.

Oxygen lancing then continues under these conditions until the analysis of the mixer metal is received, 1 h later. From this is calculated the blowing time to reduce the carbon content of the bath to 1·0%, and at the same time form a basic slag capable of reducing the phosphorus to 0·10–0·15%.

This is a straightforward calculation from the oxygen required to oxidize the metalloids present, taking into account the initial charge ore. Graphs and tables have been prepared, initially from theoretical considerations and later corrected from practical experience, to assist the furnacemen in calculation. The latter takes into account oxygen efficiency under the conditions of operation.

After blowing for the calculated period, the furnace is sampled taking a copper-pot sample (to facilitate rapid drilling), carbometer sample, and bath temperature. At this stage the slag is fluid and inclined to froth and foam (particularly with high-silicon and high-phosphorus mixer metal, above 0·45–50% Si). The slag is now removed, provided that the carbon sample indicates a carbon content of about 1·0%. If the carbon is greatly in excess of 1·0%, blowing may be continued, with or without more ore, particularly if the slag is not fluid (i.e. undissolved lime) or if the bath temperature is below 1500° C.

During the whole blowing period the steam jets have been turned on to direct the vigorous reactions developed immediately above the lance on to the furnace bath. They have an added advantage in that they reduce the tendency of the slag to foam.

The slag is removed with the furnace firing normal fuel, the slag subsiding gradually as it is removed. If the slag is removed during oxygen lancing it is found to be very frothy and sponges over the top of the slag pans. The slag iron content varies from 10·0% to 20·0%. These high slag-iron slags are undesirable owing to the loss of iron, and the tendency for foaming, which makes furnace operation more difficult. Experimental work is continuing to determine a method of reducing the iron content to the normal 9·0%, but this is not yet fully under control.

As soon as the slag has been removed burnt lime and iron ore are added as required. The lime addition follows normal slag control practice at Appleby-Frodingham, but burnt lime is used instead of the raw limestone used in the conventional furnace. The ore addition is made on the basis of a thermal balance: i.e. as much ore as possible is added to allow oxygen blowing to continue to raise the bath temperature to 1560° C, and also to form the final slag to reduce the phosphorus to below 0·05%.

A graph enables the melter to calculate the quantity of ore to be added and the blowing time to reduce the bath carbon down to 0·40%. At this stage the furnace reverts to normal firing and tapping starts.

Fettling and Taphole Maintenance

The consumption of dolomite has been equal to that of a conventional furnace but, in view of the excellent condition of the bottom and banks after a 6-week campaign (the banks only showing wear high up on the slag line), it is hoped to reduce both the fettling time and the dolomite consumption. This is due to an important characteristic of the furnace, in which the bath and slag temperatures are low throughout the charge, only increasing at the final stages of tapping.

Quick-cycle Operation

The furnace taps every 7–8 h, compared with the normal 14–16 h of a 300-ton conventional furnace. This results in a quicker turnround for the furnace crews; such operations as fettling the launder, closing the taphole, and bank fettling have to be performed once every 8-h shift instead of every two shifts.

In this respect it is to the furnace crews' credit that they have adapted themselves so well to the new method of working. It has been quickly realized by everyone that even small delays in such a short-cycle operation result in a big loss in output, and for this reason every effort is made to ensure adequate and speedy servicing of the furnace.

Discussion of Operational Data

Table II shows an analysis of the varying methods of operation over a period from 11th February to 15th May, 1958; the data relate to a total production of approximately 40,000 tons of finished steel ingots. Test groups 1, 2, and 3 are using a flow rate of about 60,000 ft³/h, whilst the remaining groups are variations of 40,000 and 50,000 ft³/h.

It is difficult to make direct comparisons between each group, since the quality of iron affects greatly the production rate, giving rise also to a variation in the consumption of iron ore and oxygen.

The higher production rates of groups 2 and 3 (lower metalloids) and a high flow rate (60,000 ft³/h) are to be noted. In group 9 the lower tons per hour is due to periods of very high-sulphur iron (0·10–0·15%), which, although reflected to some extent in the average sulphur at 0·075%, seriously reduced the output rate during this time.

In all trials the low consumptions of total oxygen (less than 1600 ft³/ton), and low therms per ton (less than 13 therms/ton) are to be noted.

The high consumption of ore up to 10% is also exceptional for the low gas consumption, indicating the high thermal efficiency of the process and utilization of the heat available in the pig iron.

Table III shows the analyses of the slags and bath samples at slag-off and tapping in six of the groups shown in Table II. Similar analyses for normal open-hearth slags are also recorded.

When comparing the two processes it is to be remembered that the number of charges for the oxygen furnace are relatively small, and in these circumstances positive conclusions cannot be made. However, the following are of some consequence:

(1) The bath slag-off and tapping samples vary little except for the lower manganese in each case, and the higher carbon at slag-off of the oxygen process.

(2) The sulphur content of the bath at slag-off and tap is to a very great extent dependent upon the sulphur of the ingoing mixer metal. Nevertheless, the sulphur content of the slag-off slag is much lower than normal, whilst the tapping slag is comparable with the conventional process. Accordingly there is some evidence of sulphur removal into the gaseous phase (above normal), particularly as the sulphur pit analyses in both processes are identical. The waste-gas analyses also confirm this.

(3) The slag analyses at both slag-off and tapping differ appreciably as follows:

(*a*) The total Fe content is much higher
(*b*) The CaO content is lower, although the MgO is slightly higher, indicating that more dolomite is being taken into solution
(*c*) The P_2O_5 content is higher (an important factor in steelmaking economics, because of the sale of the slag as a fertilizer)
(*d*) The Cr_2O_3 content is higher, indicating the attack of the basic CrMg roof, and subsequent solution in the slag (*see* Table III).

One further interesting point is the high SiO_2 contents of the slags in group 2—i.e. when the roof had been patched with silica bricks and the effect of the melted SiO_2 on the slag composition.

Results Achieved

The results achieved over a period of nine weeks' operation in March–May, 1958, are recorded in Table IV. These are representative of what is present standard practice and are described under two main headings: consumption of raw materials and productive data, and steel quality.

Consumption of Raw Materials

These are recorded in Table IV; the high consumption of oxides and low consumption of oxygen and fuel are to be noted.

Yields are lower than in the conventional process largely owing to the higher iron loss (as oxide) in the slag. In this respect the loss has been minimized by careful control of the slagging-off technique to avoid metallic losses in the slag as shot.

This loss of iron as oxide in the higher slag bulk (2·80 compared with 2·40 cwt/ton) as a higher Fe content of 16·01% compared with 7·5% accounts for 1·35% of metallic yield; in addition, because the process uses 100% metal, there is more loss due to oxidation of C, P, Si, and Mn.

Table IV indicates a credit for recoveries of 0·07 cwt/ton—the dust recovered from the dust cleaner, checkers, and slag from the uptakes and slag pockets expressed in units of iron. These are expressed in more detail below:

	Fe, %	*Fe loss, cwt/ton*
Dust (from dust cleaner)	65	0·028
Flue dust (from checkers and flues)	50	0·01
Slag	33	0·033
Total		0·07

The low quantity of dust (fume loss) from the dust cleaner is equivalent to a loss of only 0·10% of iron charged. However, during this period only 75% of the gases were cleaned, and in addition the cleaner was also out of commission for short periods for bag changing. A more realistic figure under these conditions is thought to be 0·2% loss.

There is a 14% increase in the production of basic slag of improved quality (higher P_2O_5 content), although until considerable quantities have been tipped on the slag bank and passed through the grinding mill it is not possible to assess the improvement. However, this is an important factor in the economics of the ingot manufacturing costs due to the increased value of the slag as a fertilizer.

Steel Quality

The sulphur, phosphorus, oxygen, and nitrogen contents of oxygen-produced steel are identical with

Table IV

CONSUMPTION OF MATERIALS AND PRODUCTIVE DATA

8th March–17th May, 1958

	Oxygen Furnace	Normal O.H. Furnace
Tons per working week	4070	3210
Gross hours per week	168	168
Stoppages per week, h	15·1	10·0
Tons per gross hour	24·23	19·11
Tons per net hour	26·63	20·32
Yield: ingot, %	97·30	90·00
metallic, %	91·31	94·15
Mixer metal, cwt/ton	21·02	17·02
B.F. iron, ,,	0·23	—
Scrap, ,,	0·16	3·55
Finishings, ,,	0·20	0·20
Oxides, ,,	2·00	2·23
Total metallics, ,,	23·61	23·00
Credit: pit scrap, cwt/ton	0·85	0·92
recoveries, ,,	0·07	—
Net Metallic	22·69	22·08
Fluxes: Burnt lime, cwt/ton	0·64	0·20
Limestone, ,,	0·24	1·44
Dolomite, cwt/ton	0·60	0·64
Oxygen: Lance, ft³/ton	907	—
Combustion, ft³/ton	523	150
Fuel: Coke-oven gas, therms/ton	13·6	—
,, ,, + pitch-creosote therms/ton	—	46·0
Analysis of mixer metal, % C	3·32	—
P	1·05	—
Mn	0·57	—
Si	0·29	—
S	0·057	—
Slag, cwt/ton	2·80	2·40

the normal open-hearth steel, and in this respect there appears to have been no effect on the chemistry of the process. This is to be expected as the charge is finished off and tapped as a normal O.H. furnace, with the possibility of a slightly more vigorous boil.

Instrumentation and Oxygen-control System for 'Ajax' Furnace and Ancillary Equipment

By R. A. Kipling, Assoc.Eng.

The instrumentation adopted some years ago as standard for the Appleby-Frodingham open-hearth furnaces comprised:

Measuring Instruments

Coke-oven gas, blast-furnace gas, air and pitch-creosote flow recorders; roof, regenerator top, waste gas to chimney and pitch-creosote temperature recorders; chimney draught, furnace pressure, steam and pitch-creosote pressure recorders; coke-oven gas, regenerator top and bottom pressure indicators.

Automatic Controllers

Roof temperature, furnace pressure, blast-furnace and coke-oven gas pressures, air/gaseous-fuel ratio.

This standard has had to be considerably augmented and revised for the 'Ajax' furnace, mainly owing to the increased speed of operation when using oxygen, the change in the nature of the process, and the design of the furnace.

The increased speed of operation has necessitated all the main controls and indicators being arranged centrally on a control desk (Fig. 6), while the recorders and subsidiary indicators are retained on the main instrument panel (Fig. 7).

To achieve this the air, gas, and oxygen volume control valves have been made remotely operated and the provision of rapid hand adjustment for the furnace pressure level has had to be added.

The change in nature of the process has necessitated the addition of instruments for the control and metering of oxygen and for the assessment of the waste-gas composition. The dense iron-oxide fumes which are a characteristic of an oxygen-blown furnace have

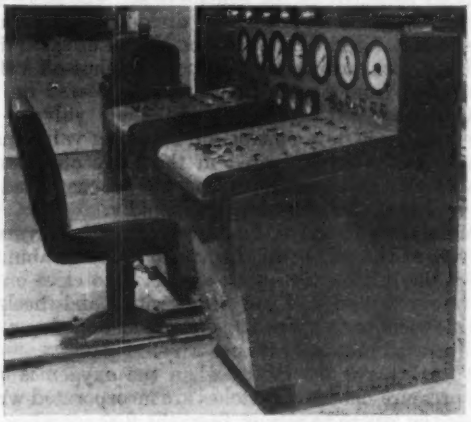


Fig. 6—Control desk

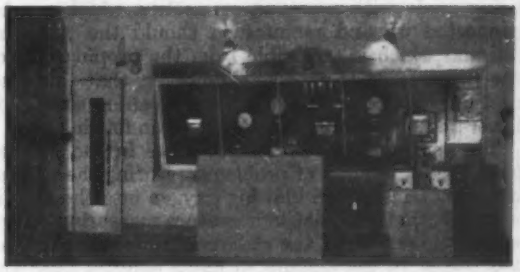


Fig. 7—Instrument panel

resulted in a number of changes being made to the temperature-measuring equipment.

The modifications to the design of the furnace and the addition of a waste-heat boiler have also caused a revision of the instrumentation. The blast-furnace gas metering and control system have been removed and the furnace-pressure control system has been modified to operate on the boiler induced-draught fan control vanes.

Furnace Instrumentation

The air and fuel meters are of the same types as those fitted to the other furnaces at Appleby-Frodingham, with the exception that pneumatic remote transmitters have been added to the air and coke-oven gas flow meters to enable the readings to be indicated on the control desk. The indicators on the desk are located immediately above the respective push-button switches which operate motorized gear boxes connected to the air and gas control valves.

As pitch-creosote is an emergency reserve fuel, only the flow recorder has been mounted on the main instrument panel, the temperature and pressure recorders being located at the rear of this panel.

The addition of the waste-heat boiler and the endeavour to obtain a tightly sealed system has placed additional importance on the furnace-pressure controller. It was immediately realized that continuous blowing of oxygen with the resultant oxide fumes within the bath would cause trouble by choking the pressure connection in the roof of the furnace. An auto-manual control valve located on the control desk has been added to the existing furnace-pressure equipment to permit the pressure in the furnace to be manually controlled when necessary; in addition the speed of operation of this controller when hand-operated has been increased to enable the furnace pressure to be reduced rapidly when taking samples, etc. Normally this pressure controller actuates a regulating cylinder on the induced-draught fan vanes at the waste-heat boiler. If it is found necessary to by-pass the boiler and operate the furnace straight to the chimney stack, the pressure controller can actuate a cylinder attached to the chimney damper, the change-over manifold being located at the waste-heat boiler.

Experience so far with furnace-pressure control indicates that trouble with the impulse connection of the roof-pressure controller only arises on the last few days of the roof life, when its thickness is only a few inches. In these circumstances it is unsafe to go on to the roof to attend to the connection. To keep the control working automatically, experiments are

being made with a second connection which can be connected up and maintained should the first one fail and which is accessible from the tapping side of the furnace. It is expected, however, that this connection will require more regular cleaning since it is lower and more liable to choking when fettling, etc.

The measurement of temperatures in the furnace has raised a number of problems. During the preliminary experiments on blowing oxygen into the bath it was seen that the roof-temperature measuring equipment, which was of the radiation type, became useless owing to the amount of oxide evolved from the bath. The Research and Development Department of the United Steel Companies Ltd. was therefore requested to carry out research into alternative methods of measurement of high temperatures under these conditions. The first method suggested was to use thermocouples of the 5/20 Pt–Rh type inserted in sheaths made of spinel. These sheaths protrude approximately ½ in. below the hot face of the roof. It is also proposed to try radiation units sighting on refractory discs sealed into the bottom of special bricks built into the roof. A separate report is included on work done in connection with this problem.

Another problem concerning the measurement of the regenerator temperatures has had to be dealt with, as it was visualized that when blowing oxygen there would be a tendency for the temperatures and conditions at the tops of the regenerators to approach those within the furnace. Consequently the problem of measurement became similar to that for the furnace roof. The same type of platinum thermocouples have therefore been used. They have been inserted in magnesia inner sheaths with silicon carbide outer sheaths to protect them from attack by iron oxide when blowing. It is appreciated that there may be a tendency for the silicon carbide sheaths to be oxidized if the waste gases contain much excess oxygen.

Operating experience to date has shown that the temperatures at the top of the regenerators are somewhat lower than was originally expected and are generally between 700° and 1200° C, seldom exceeding 1300° C. Also, the atmosphere is oxidizing for the major part of the charge. Under these conditions there has been no iron-oxide attack or direct oxidation of the silicon carbide sheaths. It is now felt that a life equal to the time between checker changeovers can be anticipated. Couple lives in excess of 60 days have already been obtained.

As the furnace is coupled to a waste-heat boiler the regenerators are small and cause only a relatively small temperature drop of the waste gases. It is expected, however, that it will be sufficient to allow the standard 13%Pt/Rh thermocouples used in mullite sheaths similar to those used on the other open-hearth furnaces to be used at the bottom of the regenerators. To start with, the couples and sheaths are enclosed in silicon carbide outer sheaths to give additional protection from iron-oxide attack.

The ideal instrument to provide and show data on combustion conditions in the furnace bath should have a centre zero with an indication of oxygen content of the waste gases on one side and the carbon monoxide content on the other. Since such an instrument was unobtainable, use has had to be made of two analysis units for the oxygen content and the carbon monoxide content respectively, each with its own recorder. These are mounted adjacent to one another on the main instrument panel and the readings are transmitted to indicators on the control desk. The oxygen analysis meter is of the magnetic type and the carbon monoxide meter of the infra-red type. Gas samples are taken from the bottoms of each regenerator by means of steam injectors, washed, filtered, and fed to the analysing instruments located in the instrument cubicle by $\frac{3}{16}$-in. bore copper tube. The reversing valves provided enable the sample fed to the analyser to be always taken from the outgoing regenerator. Details of the sampling equipment and the performance of the analysers are given later.

Oxygen Control System

Another section of the instrumentation which gave rise to new problems was the control system of the oxygen supply, though some experience had been gained during the preliminary trials while operating with comparatively large flows of oxygen.

The main design features of this equipment are:

(1) Copper tube has been used throughout so as to enable higher pipe velocities to be used without the risk attached to steel pipes
(2) All valves where velocities must be high are made of brass or bronze with stainless-steel trims, no mild steel or iron being in contact with oxygen
(3) Where control valves must also be of the shut-off type, fluon sealing washers are incorporated
(4) All glands are packed with non-combustible materials and lubricated with special greases.

After passing through the main stop valve, the oxygen pressure is reduced from the normal line pressure of 200 lb/in² to 165 lb/in² by means of pneumatic controller operating a 3-in. valve. This provides a constant pressure for metering and will maintain a stable flow when the flow-control valves have been set to the required position.

After the pressure controller the main is divided into three streams for lances, coke-oven gas burners, and air enrichment respectively. Each stream has its orifice plate connected to the respective flow meters followed by pneumatically operated flow-control valves. These are operated from pneumatic control stations mounted on the control desk. The lance and burner oxygen lines in turn are divided into two lines, one to either end of the furnace. Each of these lines is fitted with pneumatically operated shut-off valves controlled from pushbutton switches located on the control desk via solenoid-operated air valves. All the pneumatic flow control and reversing valves have needle valves incorporated in the relay air lines to enable the speed of operation to be controlled to prevent them being opened too rapidly.

Main shut-off valves are fitted after the reversing valves, at the end of the furnace operating cabin.

All the pneumatic valves are made to close on air or power failure and are fitted with handwheels to enable them to be opened again so that the system can be operated manually if necessary.

To safeguard the lances when the oxygen is shut off, pressure-operated switches are incorporated which cause the lances to retract from the furnace when the oxygen pressure falls below a preset value.

The oxygen flow recorders, of the mercury-manometer type, are fitted with pneumatic transmitters which operate indicators immediately above the oxygen-flow control stations on the control desk.

Boiler Instrumentation

The waste-heat boiler instrumentation is relatively simple and comprises a 2-point recorder for draught at inlet and outlet of the economizer, an indicator for draught at the boiler inlet, a steam-flow recorder, a steam-pressure recorder, and a 6-point recorder for waste gases and water and steam temperatures.

Although originally designed for use on a normal open-hearth furnace, the boiler is now connected to a furnace operating with oxygen and therefore under conditions far from the original ones. There is thus a possibility of the temperature of the waste gases entering the boiler being at a higher level than the superheater tubes could stand. To avoid such an occurrence a recirculation flue was built between the boiler inlet and outlet, fitted with a vertical-spindle butterfly valve. A temperature controller has been installed to operate this valve and thus maintain temperature of the inlet gases below the safe limit. Experience has shown that this control is not necessary.

The flow of waste gases through the boiler is controlled by the furnace-pressure regulator, which operates the induced-draught fan vanes by means of a hydraulic cylinder. The induced-draught fan is of the two-speed type, the changeover of speeds being achieved by limit switches actuated by the piston rod of the control cylinder.

All the instruments are mounted on a panel enclosed in a cubicle inside the boiler house.

Waste-gas Cleaning Plant Instrumentation

The instruments for the waste-gas cleaning plant are mounted on a panel adjacent to the boiler instrument panel so as to be convenient for the boiler attendant, who is also responsible for the gas-cleaning plant. They consist of a meter recording the flow through the plant by operating in conjunction with a Venturi tube located in the plant outlet main; a double pressure recorder giving the pressure at inlet and outlet of the filter unit, and hence the pressure drop across the filter bags; and a temperature controller which prevents the temperature of the gases entering the plant from exceeding the safe limit by admission of a controlled amount of dilution air into the inlet main.

Roof Temperature Measurement

By J. Purdie, Assoc.Met., L.I.M.

During oxygen blowing dense brown fumes are continuously given off from the bath and completely fill the furnace chamber. They obscure the field of view of the radiation pyrometer normally used for roof-temperature measurement, which is sighted through the furnace backwall on to the roof centre. Some continuous method of roof-temperature measurement is therefore required which is unaffected by changes in the furnace atmosphere.

The two methods investigated were thermocouple techniques and the use of a radiation pyrometer mounted externally on top of the roof and sighted down a special hollow brick on to a silicon carbide target flush with the inner face of the roof.

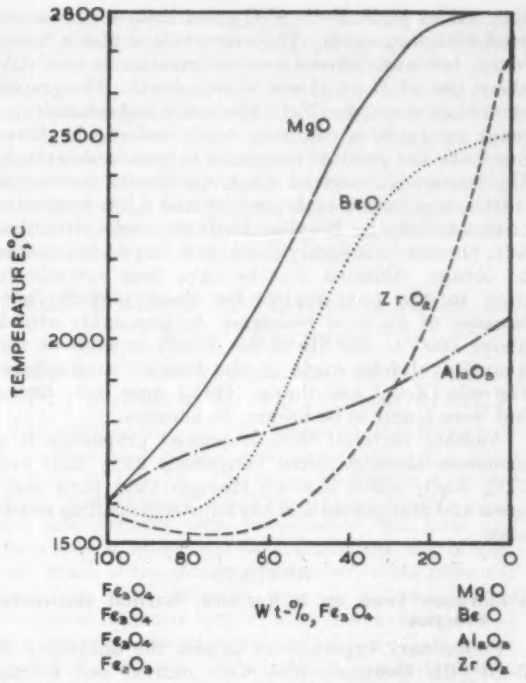


Fig. 8—Liquidus curves for binary systems Fe_3O_4–MgO, Fe_3O_4–BeO, Fe_3O_4–Al_2O_3, and Fe_2O_3–ZrO_2

The modified radiation technique was found to have severe limitations. The pyrometer measured the upper surface temperature of the target disc and so had a slow response to temperature fluctuations; it also required frequent calibration. The silicon carbide target discs were moreover rapidly slagged away by oxide. The radiation pyrometer was therefore discarded in favour of a thermocouple method.

THERMOCOUPLE METHOD

Thermocouple Materials

Thermocouples composed of 5%Rh–95%Pt/20%Rh–80%Pt were used in the early experiments. This combination may be used to measure temperatures up to 1760° C for short periods and, owing to its temperature–e.m.f. characteristic, cold-junction errors are negligible (e.g. for a cold junction at 60° C the error at 1600° C is − 3° C).

For higher-temperature applications 20%Rh–80%Pt/40%Rh–60%Pt thermocouples were used when necessary; a calibration is supplied for this combination up to 1850° C and the thermojunction fails by melting of the 20%Rh–80%Pt wire at 1895° C.

Thermocouple Sheath Materials

The chief requirements of a thermocouple sheath material are a high melting point, good resistance to iron-oxide attack, good mechanical strength, high spalling resistance, and low porosity. Unfortunately, no single material can satisfy all these requirements.

Figure 8 shows the liquidus curves for four refrac-

tory oxides MgO, BeO, Al_2O_3, and ZrO_2 when associated with iron oxide. Thorium oxide is also a possibility, but unfortunately no information is available about the effect on thoria of iron oxide. The graphs show that magnesia (MgO) forms the highest-melting-point composition with iron oxide and should therefore have the greatest resistance to iron-oxide attack. Unfortunately standard magnesia sheaths are rather brittle, and have a high porosity and a low resistance to thermal shock. Beryllia (BeO) also looks attractive but, because it is highly toxic, it is almost impossible to obtain. Alumina sheaths have been extensively used in the open-hearth for short periods, but, because of its poor resistance to iron-oxide attack above 1600° C, the life of the sheath depends on the quantity of iron oxide in the furnace atmosphere. Zirconia (ZrO_2) and thoria (ThO_2) were both tested but were found to be inferior to alumina.

Another material with improved properties is a magnesia–alumina spinel containing 28% MgO and 72% Al_2O_3 which is much stronger than pure magnesia and non-porous and has improved spalling resistance.

RESULTS

Endurance Tests on *P* Furnace, Normal Hot-metal Practice

Preliminary experiments to test the durability of 5–20%Rh thermocouples were carried out during normal working on a 300-ton tilting furnace, fitted with a chrome–magnesite roof controlled at 1700° C.

It was found that thermocouple sheaths must protrude ½–1 in. inside the roof to measure its surface temperature, i.e. the temperature indicated by a radiation pyrometer under ideal conditions. A thermocouple flush with the hot face of the roof records temperatures 20–30° C below the surface temperature (Fig. 9). The flush thermocouple is evidently affected by the temperature gradient through the roof brick and probably measures the mean temperature of a surface layer, possibly ¼ in. thick. It is therefore more sluggish in reacting to temperature changes at the surface, but nevertheless shows quite good agreement with the protruding thermocouple and radiation pyrometer and could no doubt be calibrated *in situ*.

Table V
THERMOCOUPLE SHEATH DATA

Thermocouple Sheath Material	Dimensions of Sheath	Position in Roof	Life of Thermocouple
Recrystallized alumina (Al_2O_3)	24 in. × 10 mm o.d. × 6 mm bore	Protruding 1 in., roof centre	2–6 h
Recrystallized alumina (Al_2O_3)	24 in. × 10 mm o.d. × 6 mm bore	Flush roof centre	6–10 h
Alumina sheath with outer cap zirconia paste	18 in. × 10 mm o.d. × 6 mm bore. Cap 4 in. × 20 mm × 10 mm	Protruding 1 in., roof centre	12 h
Silicon carbide outer sheath with alumina inner	Outer 18 in. × 1½ in. o.d. × ½ in. bore Inner 24 in. × 10 mm o.d. × 6 mm bore	Flush, roof centre	20 h
Magnesia sheath	24 in. × 10 mm o.d. × 6 mm bore	Flush roof centre	2 days
Spinel (MgO. Al_2O_3) outer sheath, with spinel inner cap	Outer 20 in. × 14 mm o.d. × 10 mm bore Inner 2 in. × 6 mm o.d. × 4 mm bore	Flush 2ft 6in. from back-wall, opposite No. 3 door	4 days
Spinel (MgO. Al_2O_3) outer sheath, with MgO inner sheath	Outer 20 in. × 20 mm o.d. × 16 mm bore Inner 20 in. × 11 mm o.d. × 6 mm bore	Flush, furnace centre-line opposite No. 2 door	6½ days

Several combinations of sheath materials and thermocouple positions were tested and some of the more interesting results are summarized in Table V.

Alumina sheaths protruding 1 in. through the roof were rapidly slagged away by iron oxide. Improved lives were obtained by either using a protective outer

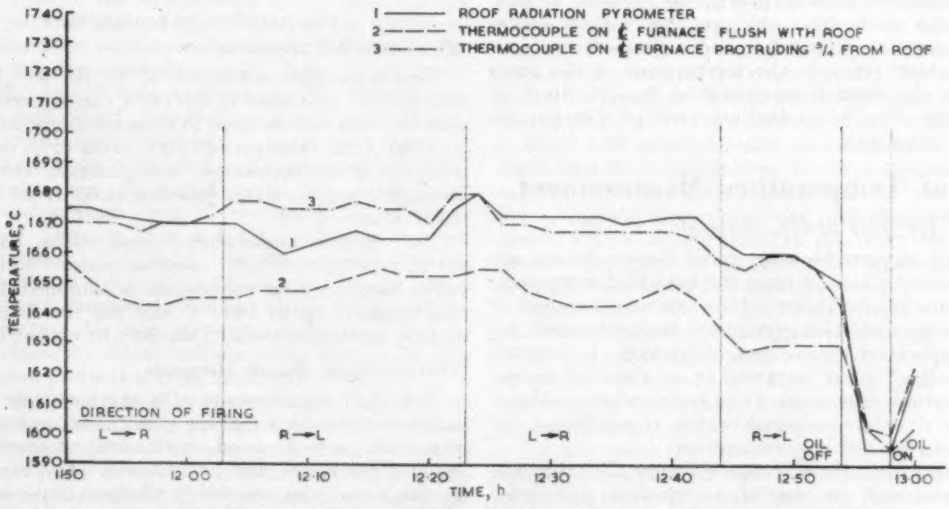


Fig. 9—Roof temperatures during refining period, *P* furnace, Appleby Melting Shop

coating or withdrawing the thermocouples so that the tips were flush with the roof.

A much greater improvement in life was obtained by using pure magnesia sheaths, but used alone they were mechanically weak and had a very low resistance to thermal shock. This was partially overcome by placing them in an outer spinel sheath.

However, even though long sheath lives could be obtained, the calibration of the thermocouples changed within a few hours owing to contamination by iron oxide which diffused through the sheath. The thermocouples therefore required frequent calibration.

Measurements on 'Ajax' Furnace during Oxygen Blowing

During the early experiments roof temperatures in excess of 1800° C were often measured, particularly above the tip of the operating lance. It was thus not possible to use 5–20%Rh thermocouples because of failure due to melting; 20–40%Rh thermocouples were therefore used.

Initially, an attempt was made to use calibrated flush thermocouples to obtain longer lives, but above the lances no worthwhile improvement was obtained. Flush thermocouples were also tried in the roof centre and above the backwall, but these showed no correlation with the temperatures in the hottest zones above the lances.

The life of alumina-sheathed thermocouples under different furnace conditions was usually 1–4 h, compared with those sheathed with magnesia-spinel, which failed after 4–6 h. This poorer showing of the magnesia-spinel sheaths compared with the previous trials was probably due to the larger quantities of iron oxide in the furnace atmosphere, which was 5–10 times that found in normal practice. The magnesia-spinel sheaths were also much more prone to spalling and were therefore difficult to replace whilst the furnace was working. Alumina was therefore considered to be a more satisfactory sheath material, even though its life was somewhat shorter.

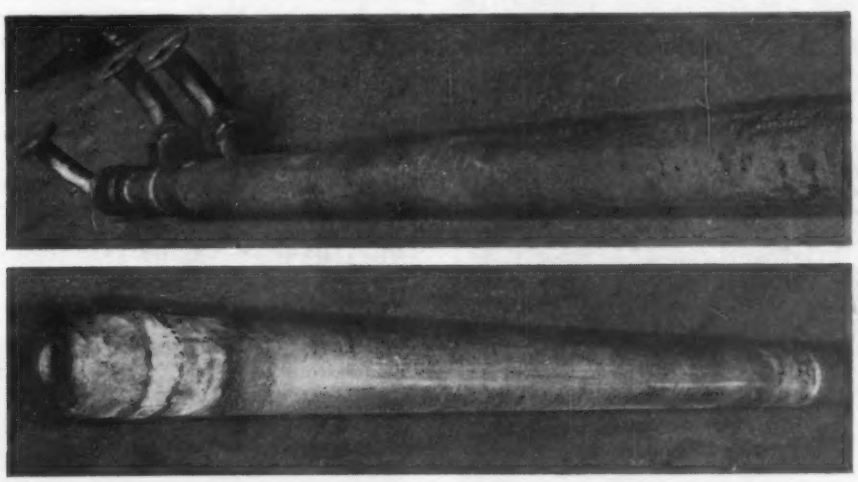
The method now established for measuring the roof temperature during oxygen blowing is that of 20–40%Rh thermocouples protruding approximately ½ in. through the roof above the tip of each lance. These thermocouples are sheathed in recrystallized alumina and packed round with alumina powder. With the degree of control now possible, in which the roof temperature rarely exceeds 1700° C, these two thermocouples will last for a whole heat and can be replaced during fettling. It may therefore now be possible to revert to the use of 5–20%Rh thermocouples, which are considerably cheaper.

Brief History of Oxygen Lances on 'Ajax' Furnace

By E. E. Clark, Assoc.Met., A.I.M., and E. F. Farrington, B.Sc.(Eng.), Assoc.M.Inst.C.E.

The arrangement of the lance on the furnace is shown in Figs. 2 and 3, and photographs of a lance are given in Fig. 10. The lance consists of a central copper pipe* through which the oxygen flows, a mild-steel intermediate pipe to separate the flow and return cooling water, and an external one, also of mild steel, which is the structural member; these pipes are concentric. The external pipe is not mild steel throughout its entire length, since it was thought that there was some risk of metal and/or slag splash at the cap end of the lance. Consequently, to assist cooling, copper pipe was used for the last 8 ft of the lance. This necessitated a joint being made between copper and steel. It was calculated that in service the working stress in this joint would be of the order of 3 tons/in². The calculated external skin temperature in the steel was 320° C and in the copper 188° C, with an internal temperature of 175° C for both steel and copper. The method of joining finally adopted was a bronze-welded butt joint. Spacer pieces are bronze-welded to the outside of the oxygen pipe and arc-welded to the outside of the intermediate pipe. These

* All copper pipe used in the lance was to B.S.1174: "Phosphorus Deoxidised Arsenical Copper."



(*a*)

(*b*)

Fig. 10—(*a*) Rear of lance, showing oxygen inlet coupling and water flow and return couplings; (*b*) front end of lance, showing copper cap and nozzle

Fig. 11—Deposit on intermediate pipe

spacers ensure approximate concentricity of the pipes and allow for movement due to thermal expansion. At the working end, the lance has a copper cap containing a nozzle. Arrangements for getting services in and out of the lance at the other end are conventional. The central oxygen pipe passes through a packed gland in the end plate.

Cooling water is directed down the inside and up the outside of the intermediate pipe. Water is drawn from the furnace-cooling system and supplied to the lance through two booster pumps, one of which is a standby. The diameter of the intermediate pipe was chosen originally to equalize the flow and return areas when using a 2½-in. o.d. oxygen pipe.

One of the earlier lances was dismantled after several hours' use to assess what trouble water scale might cause. The copper tubes showed no trace of scale. The intermediate steel tube showed some deposit, remarkable for pattern rather than amount. There were the usual stream-lines, but when copper formed the opposite wall the deposit on the steel was markedly heavier and was arranged throughout in almost symmetrical rows of isolated deposits (Fig. 11).

The lance is held in a carriage by two clamps and the cap end on an adjustable guidewheel which registers the lance with the hole in the port end. The carriage moves on four wheels in the flanges of two channels. The lance and carriage are connected by two ropes to a slightly heavier counterweight running parallel to, and below, the lance carriage. The drive is by a single rope connected to both sides of an electric winch; thus a direct pull is transmitted in either direction should the counterweight or carriage stick. The lance and carriage, being the lighter, move in sympathy with the counterweight. Should the power fail, the counterweight pulls the lance out of the furnace. The runway joists are carried on a cantilever structure hinged to a substantial bracket mounted on the neighbouring crane stanchion. This hinge permits the lance to be turned to one side, where it can be lowered to stage level for maintenance and inspection purposes. Three flexes, one carrying oxygen and two water, are permanently secured to a bracket on the lance carriage; thus the whole weight of the flex is not handled when changing lances.

Two sets of pushbutton controllers, one set for each end of the furnace, are mounted on the operator's desk in front of the furnace instrument cubicle.

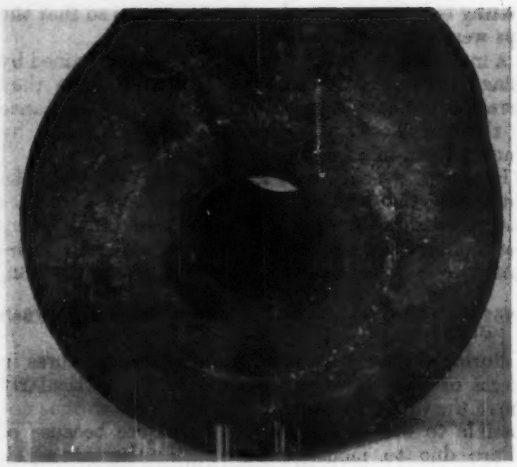


Fig. 12—Gouging out in mouth of nozzle

The lances have been assembled and repaired at the Company's own Central Engineering Workshops. It has been the practice to carry out non-destructive inspection of the lances before use, all welds being radiographed and the assembled lance tested hydraulically. This is considered to have been worthwhile since on no occasion has a weld failed in service.

Several types of caps and nozzles have been given furnace trials. So far, none has been entirely satisfactory.

Oxygen-lance failures have all been similar in type and position and always result in a water leak in the cap of the lance. Failure always takes place in the mouth of the nozzle. Figure 12 shows a typical failure: the copper has been gouged out and consequently thinned. The degree of thinning can be judged from Fig. 13, which shows a section through the leaking area of the cap. It has been shown by micro examination that the copper melts in the position where the leak occurs (*see* Fig. 14).

So far no leak has been catastrophic or interfered seriously with the working of the furnace.

Dust-removal Plant

By N. H. Turner, Dipl.Ing.(Zürich), F.Inst.F.

The use of oxygen for steel production necessitates the provision of a dust-removal plant to deal with the increased amount of suspended matter carried out by the waste gases, and avoid excessive air pollution.

The plant has to suit the type of dust produced,

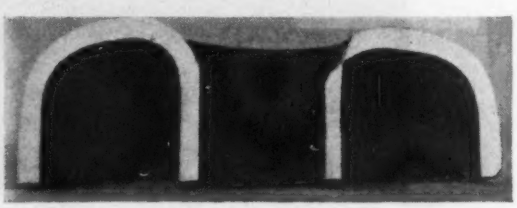


Fig. 13—Section through leaking area

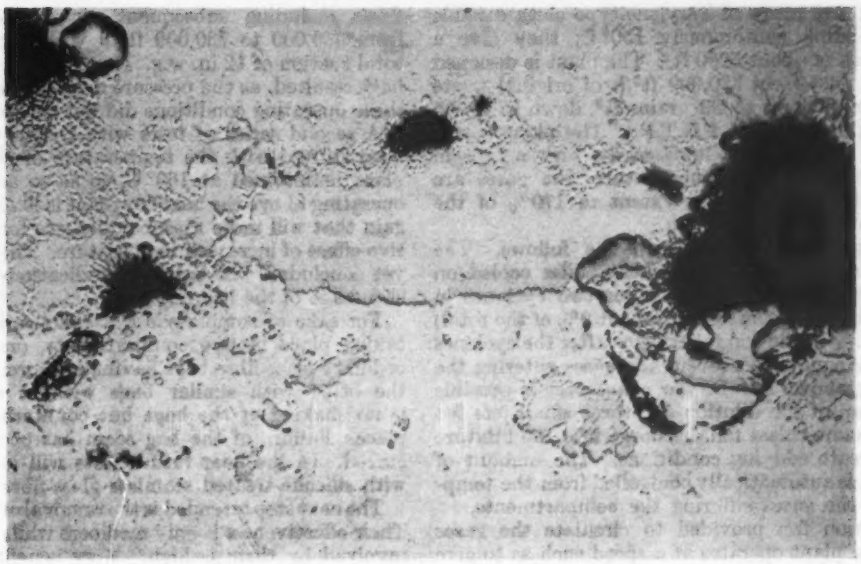


Fig. 14—Particles of steel in copper and copper in steel, indicating melting in leaking area × 100

the temperatures, and the general conditions met with. The 50 years' experience in cleaning blast-furnace gas at Appleby-Frodingham had already imparted useful knowledge on the various methods available, but precise information on the suitability of any one of these for the purpose at hand was lacking. Furthermore, the decision about the size of the plant was rendered difficult by the inability of assessing reasonably accurately what amount of air infiltration through valves, flues, etc. inherent to furnace operation had to be added to the initial amount of waste gases produced.

It was therefore decided that the plant to be incorporated would be somewhat in the nature of a not too costly experimental plant, which would also provide more reliable data for any future installation.

Wet washing, which by transferring atmospheric pollution to water creates a further problem, was eliminated leaving, owing to the fineness of the major proportion of the particles involved, only electrostatic cleaning and filtering through a suitable medium to be considered. It was therefore decided to assess the respective merits by inspecting a plant of each type known to be operating on the removal of dust from gases produced by an oxygen process.

There was no doubt in the mind of the investigator as to which of the two plants gave the most consistent results and, while it was appreciated that the operating costs were likely to be higher by using the filtering method, the moderate capital cost involved led to the decision to install a dust-removal plant of the bag-filter type, somewhat akin in operating principles to the Halberg-Beth plants used previously at Appleby-Frodingham for cleaning blast-furnace gas (Fig. 15).

The use of the bag-filter plant requires the gases to be below the safe temperature permitted by the bag material. It was expected that this condition would be met by the passage of the gases through the waste-heat boiler with which the melting furnace concerned is equipped. Provision was, however, made for further air dilution to be available before the gas entered the dust-removal plant. This has proved invaluable as, in spite of regular shift cleaning of the boiler smoke tubes, the rate of deposition of dust within the boiler is such that it is almost impossible to maintain the exit gas temperature below the limit originally contemplated. To this difficulty has had to be added at times the lowering of the safe level of temperature called for by certain of the bag materials.

This further dilution of the gases in addition to the variable initial air infiltration would at times cause overloading of the dust-removal plant were it not for provision for by-passing some of the gases directly up the chimney when needed. The details are included in the section dealing with the waste-heat boiler.

Plant Characteristics and Intended Operating Conditions

The plant decided upon has 15 compartments containing 14 bags each. The bags, of 8$\frac{5}{8}$ in. dia. by

Fig. 15—Gas-cleaning plant

10⅔ ft long, are made of Terylene-type cloth capable of withstanding continuously 150° C; they give a filtering area of about 5200 ft². The plant is designed to remove dust from 320,000 ft³/h of original waste gases containing up to 30 grains/ft³, down to 0·005 grains/ft³ (all volumes at N.T.P.). The plant is still capable of performing satisfactorily with a margin when, because of high temperature, the gases are diluted with air up to the extent of 170% of the initial volume to 550,000 ft³/h.

The sequence of operation is as follows. The gases, after leaving the waste-heat boiler cooled on the average to about 220° C, enter two cyclones in parallel, where the coarse dust (about 9% of the total) is removed. Air dilution takes place after the cyclones at a rate adequate to prevent the gases entering the bags being above 140° C. To counteract a possible stratification of the dilution air, three small jets fed from the counterblast fan discharge into the mixture so as to create eddying conditions. The amount of air dilution is automatically controlled from the temperature of the gases entering the compartments.

The suction fan provided to circulate the gases through the plant operates at a speed such as to give a suction of 8 in. w.g. when dealing with 550,000 ft³/h of gases at 100° C. The fan returns the clean gases to the melting-furnace chimney.

A fan is provided to counterblast the bags, each time they are shaken, with warmed air obtained by circulating atmospheric air round the hot inlet-gas main. The shaking of the bags is mechanical, one compartment at a time, to a cycle of 8 min.

The dust collected by the bags falls into a hopper from where a screw conveyor takes it to join the dust out of the cyclones and then through a chain conveyor to a loading bunker for removal by wagons.

The control of the satisfactory operation of the plant takes place through the intermediary of the metering provided, which includes a record of the temperature of the gases before air dilution, the temperature of the gases entering the bags, the gas flow leaving the plant, and the pressure before and after the filter bags.

Changes Made to Plant and Prevalent Operating Conditions

To avoid the possibility of undue local cooling and eventual moisture deposition, the whole plant has been thermally insulated.

The Terylene-type bags originally used for the sake of a reasonably safe high level of operating temperature proved unsatisfactory as, owing to the presence of sulphur compounds in the waste gases, almost immediate failure of the material resulted. They were replaced by Orlon-type bags, which although not capable of operating at as high a temperature as Terylene, were expected to be superior in their resistance to the chemical attack involved. The safe limit of temperature within the dust-removal plant was for this purpose reduced to 130–135° C. These bags lasted on the average seven weeks. While improved bag life was obtained, the increased air dilution needed rendered the plant capacity fully inadequate. To augment this capacity the speed of the suction fan was increased as far as was permitted by the power of the motor driving it and the flow of gases including subsequent air dilution went up from 550,000 to 730,000 ft³/h with a corresponding total suction of 12 in. w.g. No excessive strain on the bags resulted, as the pressure drop across them under these operating conditions did not exceed 3 in. w.g.

A second series of tests with Orlon-type bags has been started with the temperature of the gas in the plant maintained at 160° C, so as to assess whether operating above the acid dewpoint is likely to lead to a gain that will more than compensate for the destructive effect of increased temperature. The tests are not yet concluded, but there are indications of excessive shrinkage of the bag material.

For sake of comparison a parallel series of tests is taking place in two compartments, one fitted with ordinary glass-fibre bags having reinforcing rings, and the other with similar bags without rings. There is no shaking of the bags but counterblasting takes place. Failure of the bag seam has occasionally occurred. In the near future tests will be undertaken with silicone-treated seamless glass-fibre bags.

The next step intended is the removal of the cyclones. Their effectiveness is only mediocre while pressure loss involved by them is high. More benefit is expected from the increased capacity of the fan following their removal than will be lost by the increased dust deposition on the bags between cycles of operation.

So far the filtering efficiency has remained good with any of the bag materials used.

Some Fuel Engineering Aspects

By S. H. Brooks, B.Eng., M.Inst.F.

WASTE-HEAT BOILER

Layout and Design

The boiler system was designed and ordered for a normal furnace, before the decision was made to convert the furnace. Consequently it might have been a little smaller and have had certain modifications if it had been designed for the job. The layout is shown in Fig. 16. The boiler is a 13 ft 6 in. dia. firetube type, with 2¼ in. dia. sinuflo tubes, capable of operating at 250 lb/in² (present operating pressures are about 190 lb/in²). Stand-pipes are provided in case evaporative cooling is applied to the furnace in the future. The superheater is of the radiant type, so as to be less susceptible to blockage than convection designs, and a gilled-tube economizer follows the boiler, with suitable by-passes. The layout is designed to leave a clear space between this boiler and one fitted on an adjacent furnace for tube cleaning. Both are in the same house for ease of supervision. The boiler and stack damper counterbalance one another, an electric motor operating the dampers in tandem.

Steam and electric feed pumps and a continuous-blowdown heat exchanger are provided. The intermittent blowdown passes through the large fire tubes of the old Lancashire boiler used as a feed tank.

The fan has backward-inclined straight blades and operates at an efficiency approaching that of the aerofoil design, though of simpler and cheaper construction. Draught is controlled (automatically or manually from the furnace or, in emergency, manually from the boiler house) by inlet vanes operated by a

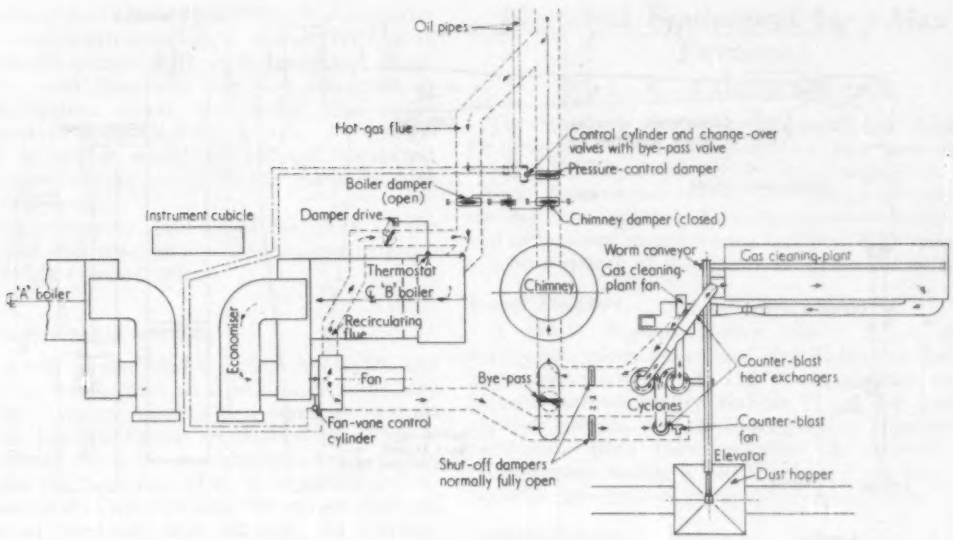


Fig. 16—Layout of boiler and gas-cleaning plant

servo-cylinder. The rated fan capacity is 63,000 ft³/min at 11 in. w.g. and 386° F and it is driven by a 150-h.p. two-speed motor with provision for automatic change of speed operated by adjustable limit switches on the vane-operating mechanism; this ensures minimum power wastage.

Modifications

Following the decision to build an ' Ajax ' furnace, decisions had to be taken about boiler design before much experience of the process could be gained. At that time it was thought that waste-gas temperatures at the boiler could easily reach 1000° C for long periods with low volumes and hence low steam make. The boiler manufacturers were unhappy about temperatures exceeding 1000° C, and in any event superheater-metal temperatures would be above the safe limit under these conditions.

The superheater heating surface was therefore reduced to about one-third of the original specification and a waste-gas recirculating duct was incorporated; this connected the fan outlet to the boiler inlet and contained a butterfly valve which was automatically controlled to maintain any desired waste-gas inlet temperature at the boiler (*see* Fig. 16). Because of the possibility of low gas volumes, the fan was modified to give better sealing on the inlet vane control.

In practice the gas recirculating duct has not been required, as furnace practice has differed from that anticipated when the decision was made; it has now been blanked off, though such a device could be useful in controlling steam temperature if that were necessary. Likewise the superheater has proved to be too small and superheat has averaged about 475° F instead of the required 660° F. The original design of superheater will be installed at the earliest opportunity.

Another special modification concerned the waste-gas bypass. Because it was known that the dust-collecting plant was on the small side and could certainly not handle the gases produced during the fuel firing period, it was necessary to provide a bypass around the gas-cleaning plant. This took the form of an inverted U-shaped duct (4 ft dia.) joining the dust-plant inlet and outlet flues. It was provided with a butterfly damper but it was intended that this should normally be wide open, so that the gas-cleaning plant could be run at a substantially constant volume (by virtue of the constant-speed fan), with surplus gas bypassing the plant or deficiency being made up by recirculating a portion of the clean gases. In practice this has worked well, although there has always been surplus gas passing to the stack.

Cleaning and Operating Practice

The original plan, with ordinary furnaces, was to have one man per shift to attend and clean two boilers; he was to clean one-third of the tubes on each boiler by air lance, and to air-blow the superheaters and the underside of the economizer tubes in addition to operating the economizer steam soot-blower.

One air lance is provided for cleaning both boilers, with its hose permanently attached to a central overhead point; a movable two-level platform is provided to gain access to the upper tubes. The lance is of $\frac{1}{2}$ in. tube having a nozzle similar to that used at Colvilles* but with all the holes (13 at $\frac{1}{8}$ in. dia.) pointing backwards to blow the dust towards the exit of the boiler. The lances are pushed right through the tube and successfully clean the inlet-tube plate. Tests revealed that this type of lance gave much better results than a short lance with a pulsating air flow.

A lance with overhead suspended hose is also provided between the two economizers. This is of $\frac{1}{2}$-in. bore drilled with six $\frac{5}{32}$-in. dia. holes arranged to give a fan-shaped jet, so that it has merely to be pushed in and out of the holes provided below the tube bank. Similar lances are permanently fixed at each side of each superheater for cleaning these units.

* R. McDonald, *J.I.S.I.*, 1954, vol. 176, pp. 71–92.

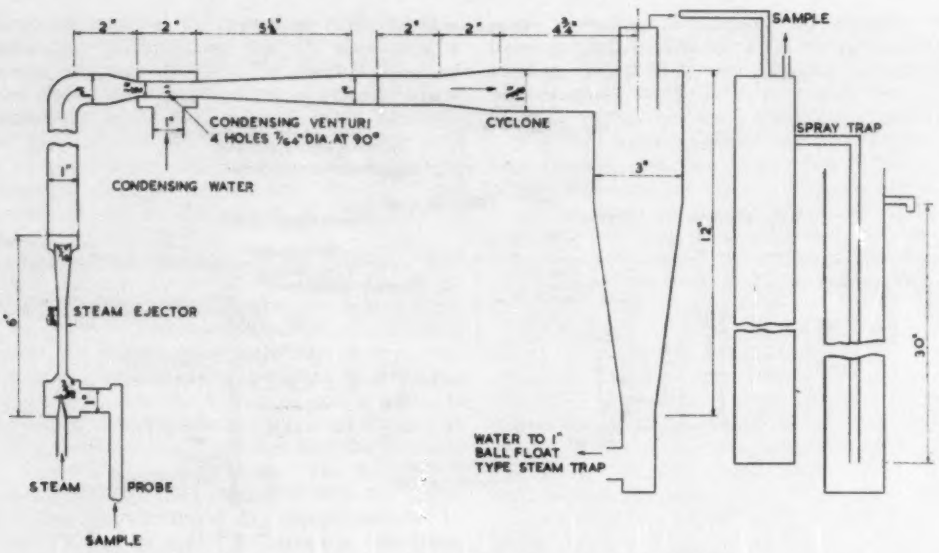


Fig. 17—Sampling apparatus for continuous waste-gas analysis

These provisions appear to be quite satisfactory with the normal furnace boiler, but special problems have been created by the high dust burden from the 'Ajax' furnace. During oxygen blowing dirt can build up rapidly, resulting in an increase in exit temperatures and hence a reduction in gas volume passing to the gas-cleaning plant. Because of this it was decided that each tube should be cleaned every shift, and an extra man has been required. It is doubtful whether the target has been attained but exit temperatures are reasonable, at about 220° C, if not at the lowest theoretical level.

MISCELLANEOUS ITEMS

The object of this section is to make brief reference to several interesting if relatively minor features of design and operation that are not mentioned elsewhere.

Air Purge System

Purge air is used to keep oxygen lances, burner oxygen nozzles, and roof-pyrometer sight holes clear. It is automatically turned on to the nozzles and lances whenever oxygen is turned off. The bulk of the air is passed through the large nozzles of the lances.

The air is supplied by a single stage fan rated at 500 ft^3/min at 45 in. w.g. driven by a 10-h.p. motor. The fan is situated in the valve arch and delivers through a 5-in. dia. main with 4-in. branches to each end of the furnace, which finally branch to 3 in. and 2 in. supplying the lance and the burners respectively.

On normal furnaces compressed air is used for oxygen-nozzle purge; the system described above will cost about £2000 per year less in power than the use of compressed air (100 lb/in^2).

Transmission of Analysis Information

Because of the increased tempo of operation, it became clear that quicker communication between the laboratory and the furnace would be of value. Creed teletape transceivers have been installed, first on the 'Ajax' furnace and later for the whole shop. These permit a message to be written on special paper tape $\frac{3}{4}$ in. × 13 in. and for this to be transmitted in 18 s to the receiver. The special paper costs about 1*d.* per message. The laboratory can transmit to any furnace and messages can be sent in the reverse direction.

Lance Water Cooling

The water-cooling design data are given elsewhere, but it is interesting to note that the water required by the lances (about 330 gal/min each) is just about balanced by the reductions in requirements due to the smaller furnace and port-end chills and the elimination of the long burners and various port-end brickwork support coolers of a normal furnace. Extra water has, however, been required for spray cooling and for valve cooling and sealing.

The heat extracted by the lances has been found in practice to average slightly less than 20 therms/h, which is considerably less than the theoretical, owing to the insulating effect of the slag cover formed. The overall heat losses in cooling water are between 175 and 200 therms/h, which is of the same order as for a normal furnace.

Air Infiltration

It will be clear from the furnace design that every attempt has been made to reduce air infiltration to a minimum. It was, however, decided to retain the existing brick flues across the stockyard, firstly because the furnace was experimental and replacing the flue would have been costly, and secondly because of the practical difficulties of ensuring a low enough metal temperature with a buried steel-encased flue.

Infiltration checks have been made on the system by waste-gas analysis, and it was confirmed that up to the base of the checkers infiltration was negligible. From this point to the entrance of the waste-heat boiler the calculated infiltration was 350,000 normal

ft³/h at a draught of about 2½ in. w.g. This compares with the total infiltration on a normal furnace of about 1,000,000 normal ft³/h at a draught of about 1·3 in. w.g., and illustrates the vast improvement made. Infiltration across the boiler was about 200,000 normal ft³/h, making a total of 550,000 normal ft³/h, which would be reduced somewhat during oxygen lancing owing to the lower draught during that process.

Following refractory spraying of the inside of the flue, the total infiltration in the flues has been reduced to about 250,000 normal ft²/h.

Continuous Waste-gas Analysis

It is the aim to analyse for carbon monoxide and oxygen in the waste gases on a continuous basis, and instruments were required which have an output suitable for possible future application in an auto-control scheme. Since the paramagnetic type of oxygen recorder has been proved to be a reliable instrument, it was an obvious choice for the oxygen analysis. An infra-red analyser was selected for carbon-monoxide analysis, although one had not been used on the works before.

Owing to the virtual elimination of infiltration up to the checker bottom it was decided to sample from the checker outlet flue. Sampling apparatus is situated at each end of the furnace delivering a continuous stream of gas through $\frac{3}{16}$-in. pipes to the analysers at the panel. A solenoid operating valve, tied into the furnace reversing system, directs the appropriate sample to the analysers and vents the other to atmosphere.

The sampling apparatus is shown in Fig. 17. A steam ejector draws the sample through a water-cooled probe and delivers it to a Venturi scrubber where the steam is condensed and the gas washed. A small cyclone, drained by a float-type trap, removes the water and dirt before the sample passes to the panel. Seals are fitted to avoid the possibility of water passing to the instrument.

The ejector operates on a steam pressure of 60 lb/in², taking 22 lb/h of steam and giving a sample delivery pressure of 3½ lb/in². The condensing and scrubbing water is supplied at 10 lb/in² and 2 gal/min, and the final clean sample delivery pressure after the cyclone is 30 in. w.g., giving a sample flow of 0·1 ft³/min. Sample lag is less than 20 s, and the oxygen analyser has a further lag of about 1 min, the carbon monoxide instrument giving practically instantaneous response.

Experience so far has shown this apparatus to be very satisfactory, the sample emerging from the cyclone clean and free from water droplets. The difficulty of gas absorption in the water is largely overcome by using recirculated cooling water which is discharged from the sampler at 35–40° C, at which temperature absorption is negligible.

The only major difficulty encountered, which is still unsolved, is that of sample probe blockage; the apparatus can only run continuously if the probe is cleaned at least every 8 h. Some improvement has been effected and efforts are being made to develop a probe requiring less attention.

Electrical Equipment for 'Ajax' Furnace

By L. H. Walton, A.M.I.E.E.

The standard electrical equipment for Appleby-Frodingham open-hearth furnaces has been duplicated as far as possible for obvious reasons but, when 'Ajax' furnace was rebuilt, the change in operation resulted in a departure from the standard installation and introduced many special features. The following is a brief survey of the electrical equipment involved.

Power Supplies

A 440-V, 3-phase, 3-wire, and a 220-V 2-wire supply are taken from local distribution to feed the appropriate control A 110-V single-phase centre-tapped earthed supply and 24-V a.c. are used for control circuits and indicating-lamp supplies respectively. Both these supplies are derived from transformers having a 440-V primary winding. The transformers are located in the control cubicle.

Control Panels

A multi-cubicle relay panel is provided with separate isolators for the following:

(1) Right port relay panel
(2) Left port relay panel
(3) Left port burner-gas solenoid relay panel, 220 V d.c.
(4) Right port burner-gas solenoid relay panel 220 V d.c.
(5) Coke-oven gas volume, air volume, and air enrichment relay panel
(6) Left port lance starter
(7) Right port lance starter
(8) Purge air starter and relay panel.

Existing control panels were modified for the following:

(1) Waste-gas reversing
(2) Air reversing
(3) Furnace tilter
(4) Door lifting.

Control Desk

This is shown in Fig. 6. The unit is arranged so that all controls applicable to the left and right port ends appear on the respective wings; the setting-up controls for adjusting volumes, starting fans, etc. appear on the facia panel. All internal wiring is brought to a common terminal box at the base of each wing. Instrumentation and control piping is arranged in a separate compartment to prevent accidental contact with live connections when servicing is taking place.

Five furnace-door controllers are located in the front of the wings.

Purge Air

The purge-air fan is driven by a 10-h.p., S.C. 440-V, a.c., 3-phase motor, the control of which is by a STOP–START pushbutton located on the desk, together with an indicating lamp.

The lance purge-air relay operates automatically with an adjustable time delay, i.e. on failure of the oxygen and after a short time delay the purge-air valve is opened automatically. The burner-purge air relay operates similarly with the burner gas and burner oxygen relay.

Contacts on the burner gas and oxygen relays are in series to ensure both gas and oxygen are 'off' before purge air can be supplied.

All purge-air relays are interlocked with the fan-motor starter so that they will not operate when the fan is not running. The relays operate the solenoid-operated purge-air valves rated at 50 W, 110 V, a.c.

Burner Oxygen

Pushbuttons for the left and right port ends are located on the desk and operate the respective relays; indicating lamps are also fitted. The relays energize electrically operated pneumatic valves and are interlocked so that only one pair of burners can operate at one time (i.e. left or right port end). If the waste gas is changed over with the burner oxygen 'on', the oxygen valve will close.

Burner Gas

Controls similar to that for the burner oxygen are provided at the control desk, but each valve is operated by a d.c. solenoid mechanically coupled to the valve; the solenoid is rated at 264 W, 220 V, d.c.

The solenoid contactor is interlocked in such a way that the furnace air or burner oxygen must be on before the burner-gas solenoid can be energized.

Waste-gas Reversing

On the desk 'Gas Left' and 'Gas Right' pushbuttons and indicating lamps are located. The gas valves are operated by a 5-h.p. compound-wound d.c. motor coupled to a geared unit.

There are two valves for each port end; one is in use whilst the other is spare or being repaired. A limit switch is mounted on the top of each of the two valves in service. In the event of a valve change it is necessary to transfer the limit and plug in to the appropriate socket.

Relays are so arranged that the waste-gas valves cannot be changed over till both air valves are closed.

Furnace Air Valves

On the desk OPEN–CLOSE pushputtons and indicating lamps for each port end are provided. Each valve is separately driven by a 5-h.p. geared motor unit operating on a 220-V, d.c. supply. The motor unit duplicates that used for waste-gas reversal. Each valve has an ultimate limit at each end of its travel.

The gas and air valves are interlocked to ensure that only the appropriate valves can be operated at the same time; i.e. when the waste-gas valve is open at the left port end, only the air valve at the right port end can be opened.

Provision for setting up the valves has been taken care of by the addition of a changeover switch mounted at the rear of the left wing of the desk.

Air Enrichment

A switch and indicating lamp are located on the desk facia panel. With this switch in the ON position the air-enrichment relay operates in conjunction with the furnace-air reversing relay contacts.

The relay operates an electro-pneumatic oxygen valve rated at 20 W, 110 V, a.c.

Furnace-door Control

The existing five control panels and motors are used. Each door is driven by a 2-h.p., 220 V, d.c. compound-wound motor coupled to a winch unit. Limit switches are not fitted. Miniature controllers are fitted into the front of the wings of the main control desk.

Furnace Air Fan

The fan is direct-coupled to a 16-h.p., d.c., 220-V, shunt motor. The motor is started by an automatic panel controlled from pushbuttons located on the facia of the desk. The fan motor and starter were installed at the furnace before reconstruction.

To provide a wide range of air-flow control a motorized valve has been fitted in the air main. This valve is driven by a fractional h.p., 110-V, a.c. single-phase, geared motor unit and is controlled by push-buttons located on the facia of the desk.

Coke-oven Gas Volume Control

A motorized valve similar to that for air volume has been fitted.

Lance Oxygen

Pushbuttons and indicating lamps are located on the desk to operate the electro-pneumatic valves controlling the oxygen supply to each lance. The pushbuttons operate relays which energize the pneumatic valve solenoids rated at 20 W, 110 V, a.c.

Pressure switches are incorporated in series with the relays to ensure continuity of oxygen supply and to de-energize the relay in event of oxygen failure.

Also in series with the relays are the contacts of the lance traverse intermediate limit switch relay, which ensures that oxygen cannot be applied to the lance until the lance is in the furnace, and that oxygen is cut off when the lance is retracted out of the furnace.

Lance Carriage

Each lance is fixed to a moveable carriage connected to a winch driven by a 3-h.p., 440-V, 3-phase, 50 c/s, S.C. geared motor unit. Three limit switches are fixed on the track of the carriage; two are ultimate limits and the third an intermediate (to operate when the lance orifice has entered the furnace). A brake unit operated by a 3-phase, 440-V thrustor is also fitted to the winch drum.

Five pushbuttons are provided on the desk for each lance: IN, INCH IN, STOP, INCH OUT, OUT:

(1) When the IN button is pressed, the control is so arranged that the lance will travel and stop when the intermediate limit is reached
(2) The oxygen supply must then be switched on before the lance can be taken further into the furnace by the INCH IN pushbutton. The IN button is inoperative past the intermediate limit
(3) The lance with 'oxygen on' can be 'inched in' as far as the ultimate limit
(4) On depressing the OUT pushbutton, the lance will retreat to the final limit, tripping out the oxygen supply valve on passing the intermediate limit
(5) The STOP pushbutton will arrest the lance traverse in any position
(6) The INCH OUT pushbutton is provided to give a greater degree of control.

Automatic Retraction

The lance control gear is so arranged that in the event of a power failure the thrustor brake is de-energized and the lance will retract by counterweight. If the oxygen fails the lance will retract under motor control, being stopped by the ultimate limit.

Lance Cooling-water Pumps

Two pumps, each driven by a 40-h.p., S.C., 440-V, 3-phase, T.E.F.C. induction motor, are installed for this service; one pump unit is standby. The motors are direct-on-line started.

Tilting Control

A separate control pedestal is arranged adjacent to the desk for this operation. In this pedestal a selector switch is located to change over to an alternative control position at the pitside, which is only used when the furnace is being tapped.

The furnace is tilted by two 60-h.p., 220-V, d.c. series-wound motors coupled mechanically. This arrangement is standard for all electrically tilted furnaces at Appleby-Frodingham.

Port End Retraction

The port end can be retracted before tilting is carried out. The control is provided by electro-pneumatic solenoids operated by pushbuttons located in the tilting control pedestals.

WASTE-HEAT BOILER AND DUST PLANT

Power Supplies

A 6·6-kV supply is taken from the South Melting Shop Sub-station to a 1250-kVA transformer, which in turn supplies a 440-V distribution switchboard. Feeders are taken from this switchboard to the dust plant, feed-water pumps starter board, and boiler house.

Motors and Control Gear

The i.d. fan is driven by a 2-speed, 440-V, 3-phase, T.E.F.C. squirrel-cage induction motor rated at 153/67 h.p. at 985/730 rev/min. A conventional two-speed direct-on-line automatic contactor starter is used; limit switches are fitted to change speed automatically in response to furnace operating conditions. A delay of 5 s between the operation of a limit switch and a change of speed is introduced to prevent a speed change due to transient changes in furnace pressure.

The economizer recirculating pump is driven by a 2-h.p. squirrel-cage motor, and the two feed-water pumps each by 25-h.p. 2930 rev/min squirrel-cage motors, direct-on-line started.

The dust plant comprises the following drives, all being squirrel-cage T.E.F.C. motors.

- 50-h.p., 1470 rev/min for the main fan
- 5-h.p., 1440 rev/min for the counterblast fan
- 3-h.p., 33·6 rev/min geared motor unit for the shaker gear
- 3-h.p., 33·6 rev/min geared motor unit for the cyclone conveyor
- 3-h.p., 33·6 rev/min geared motor unit for the hopper conveyor
- 7½-h.p., 8 rev/min geared motor unit for the discharge elevator
- 3-h.p., 33·6 rev/min geared motor unit for the discharge lock.

These are all direct-on-line started in two sequence groups, one comprising the main fan, counterblast fan, and shaker gear, and the other the cyclone and hopper conveyors and discharge elevator, so that a fault on the conveyors or elevators will not trip the main fan and affect the gas flow. The discharge lock is not connected in sequence.

'Ajax' Furnace—Furnace Demolition

By R. B. Atkin

The design of the new furnace called for replacement of the conventional slag and regenerator chambers by two independent systems contained within cylindrical steel casings. New valve systems were also required, together with appropriate connections to the waste-gas flues.

From the early stages of planning, it was apparent that there would be no prospect of carrying out a rapid conversion programme if conventional wrecking methods were used to move the 550,000 bricks and 120 yd³ of slag which had to be cleared from the slag and regenerator chambers. There was also an equally formidable task in the waste-gas flue areas, which involved removing some 800 yd³ of filling over the flues and then demolishing some 320 yd³ of mass concrete which existed between and around them about 20 ft below normal ground level.

Everyone concerned agreed that it was essential to complete this part of the job as early as possible because the new regenerator chambers could not be erected until clearing had been accomplished; in turn, the final setting of the chambers controlled the release of other major parts of the erection.

This then was the background which prompted an investigation to be made to see how much and what type of mechanical plant could be introduced on the job with a view to clearing one regenerator chamber within seven days from gas-out of the furnace and following with the second chamber three days later. The target in the flue areas was to complete excavation and concrete demolition in both chambers within seven days from gas-out.

From these considerations, a scheme was evolved in which the job was divided into two separate operations so far as plant requirements and site access etc. were concerned; by so doing it was planned that regenerator wrecking and concrete demolition above the flues would proceed simultaneously.

For the regenerator wrecking, the idea was to use four main units of plant: one 2½-yd³ capacity forward-loading tractor shovel, one 1¼-yd³ forward-loading tractor shovel, and two ⅝-yd³ excavators.

For the flue work there was no possibility of using any mechanical plant other than light cranes (30 cwt capacity), but here the main problem was the demolition of *in situ* mass concrete blocks, some of which were 40 yd³ in volume and up to 10 ft deep. An added difficulty in this area was the water and electric services passing only a few feet overhead, which restricted the free use of explosives for demolition.

Whilst a good deal of conventional civil engineering practice was involved throughout the whole operation, the mechanical wrecking of the regenerators and the method used for concrete demolition in confined working areas are both considered to be of particular interest and are therefore dealt with below under their respective headings.

Slag and Regenerator Wrecking

The slag chambers were left intact for 8 h after gas-out of the furnace so that air could circulate freely for cooling purposes; then one of the excavators,

Fig. 18—Slag chamber demolition. Tractor shovel travelling over top of filled-in slag pockets, 12 h after gas-out

which had its bucket arm removed and a special rig attached, moved in to collapse the slag chamber arches and bring down brickwork from the uptakes.

This done, the 2½-yd³ tractor shovel proceeded to dig the brickwork and dump it in spoil heaps clear of the working site, from where it was loaded into normal steel-bodied tipping lorries by the 1¼-yd³ tractor. This sequence of operations worked very well and material was loaded away at this stage at the rate of 25 yd³/h until brickwork had been reduced to about 3 ft below ground level (*see* Fig. 18).

Up to this time, the steel casing around the chambers had been left standing on three sides; it proved useful in retaining material against the thrust of the tractor shovels and also enabled work outside the casings to proceed without hindrance.

The lowered level which had thus been achieved provided sufficient headroom for the excavator to be travelled in over the top of the slag bed ready to dig the checker brickwork out. Its A frame had been shortened to give clearance, and it was fitted with back-actor equipment which gave a digging depth of 18 ft 6 in. below track level. However, its turning radius was such that it only cleared essential structures by 3–4 in., and particular standing positions had therefore been planned ahead so that the maximum quantity of material would be removed. During this phase outputs at each pit averaged about 10–12 yd³/h, and by the end of the third day all the bulk brickwork had been excavated to the low-level foundation pad.

The remaining operations at the deep level was to clean material from the pit bottom which had been outside the reach of the excavator. This was done by lowering the small tractor shovel into the pit by crane and pushing material within the excavator digging radius (*see* Fig. 19). This it did very effectively and then moved through to the flue area to assist with demolition work there.

The next move was to clear the slag cheese out of both air and slag pockets, upon which until this time

Fig. 19—Excavations in regenerator pits. Small tractor shovel handing material into digging radius of excavator. Concrete demolition in progress behind remains of old regenerator chamber wall

the excavator had been standing. The excavator was therefore moved back and combined with the large tractor on demolition. Watering proved useful in inducing heavy cracking and showed up weak planes which could be attacked by the tractor bucket; as pieces of slag broke away, they were pushed clear of the site for cooling and later removal. This method was effective on this occasion and undoubtedly saved time compared with earlier thoughts, which envisaged removal of the slag as a first operation before collapsing the arch brickwork.

By the methods described, one chamber was completely cleared and made ready for reconstruction to start six days after gas-out of the furnace, and the second chamber was completed three days later.

Concrete Demolition

The general view in Fig. 20, showing concrete demolition in progress, gives an impression of working conditions in the flue area, which was congested and precluded the use of heavy lifting tackle. Demolished

Fig. 20—General view of concrete demolition. Crane slewing restricted to 45° by building columns and low retaining wall in background. The clean fractures of the demolished concrete should be noted

concrete had therefore to be reduced to a size within the lifting capacity of a 30-cwt mobile crane.

With these restrictions, it was considered that the use of some form of explosives was the only method which offered any possibility of maintaining the programmed requirement of complete clearance in seven days, but high explosive was rejected because of the likelihood of damage to gas, electric, and water services which passed only 12 ft overhead, and also because of the delaying effect which would result from clearing all labour from the furnace site as a normal safety precaution.

A proprietary liquid carbon-dioxide explosive was therefore selected because it presented less of a protection problem and also localized stoppage of work for safety purposes to the immediate vicinity.

In the event, 4-ft deep holes were drilled into the concrete to take the explosive tubes. Blasting was to an open face wherever possible and a burden of about 3 ft was used. Weighted railway sleepers placed over the top of the tubes formed the only protection used and proved completely adequate. When the charge was fired, a clean fracture was obtained and lumps of concrete, 3–4 yd^3 in volume, were broken away. These were then further broken down by plug and feather and paving breakers whilst drilling for the next charges proceeded.

This part of the job was completed in eight days, one day in excess of the programmed time.

Reconstruction of *B* Open-hearth Furnace—'Ajax' Project

By

K. Paterson, *B.Sc.*, *A.M.Inst.C.E.*, *M.I.Struct.E.*

The United Steel Structural Co., Ltd., were responsible for the supply and erection of the various structural components used in the reconstruction.

Time Schedule of the Reconstruction

First instructions to proceed with the job were received by the Structural Company at the end of August, 1957, and, following discussions with other departments, site work was programmed to start on 1st January, 1958. Fabrication was planned to be completed by the end of 1957. Site work started on 1st January, 1958, and was completed to programme by the end of January.

Fabrication and Delivery

The total weight of new steelwork required was 230 tons. A start was made on the fabrication of the slag and checker chambers on 25th September, 1957, and by the end of the year all the sections were on site. The sequence of delivery had been planned to ensure that site assembly proceeded continuously.

Also, due account was taken of the difficulty of transporting pieces measuring 15 ft 5 in. long × 15 ft high and 14 ft wide weighing up to 14 tons each.

Pre-assembly and Checking at Site

Following discussions with the Production Department, a space under one of the overhead travelling cranes was cleared inside the melting shop. This enabled assembly of the slag and checker chambers to take place under ideal conditions.

These chambers were delivered in two sections, bolted together at site by means of butt straps, and, after checking to prove dimensions, were then welded up into complete units. The opportunity was then taken to do a certain amount of bricking up, and about 12 tons of brickwork was placed in each vessel, producing maximum lifts of nearly 40 tons,

Care had to be taken to ensure that, during the process of lifting the chambers and contents, the former were not distorted. This was achieved by adding certain stiffening to the plating and also by limiting the amount of brickwork which could be placed in the assembly stage.

Demolition Work, after the Furnace was Taken Off

On 1st January a start was made at site by removing the existing port ends. These were handled as complete units, each weighing about 35 tons. A large area of the stage was also opened up temporarily.

While this work was in progress the civil engineers were busy clearing out the checker brickwork below, and another gang were burning out the checker binding steelwork and having it taken away.

In spite of considerable difficulty, the demolition work went forward at a good rate and was completed to programme.

Erection of the Chambers and Ductwork

Undoubtedly the major difficulty at site was caused by the limited amount of room available for manoeuvring the large vessels and getting them into position on the foundations. To do this, it had been necessary to remove large areas of the existing floor steelwork at the stage. Also, special lifting gear and attachments were devised for fitting to the gondola on the overhead crane, and high-strength torque bolts were used through the end plates connecting to the gondola.

The four checker chambers were lowered into a temporary position under the stage floor. This was necessary owing to limited crane approach and to permit the slag chambers to be passed into position. The checker chambers were then moved over and finally connected up to the slag chambers. All flanges were jointed with $\frac{1}{4}$-in. thick asbestos rings, and these proved satisfactory.

In the valve-arch area the erection of the ducting and connections to air reversing valves were carried out working in close collaboration with the civil engineers and the various other trades.

General Comments

In a major reconstruction of this nature it has always been the custom at Appleby-Frodingham to have full discussion between interested parties and to see that major difficulties are considered and planned for ahead. Several such meetings were held before the furnace was shut down and a tight programme was then drawn up. There were also short meetings every morning between the foremen in charge of site work and the Production Manager to settle working details, crane availability during the next 24 hours, etc. There is no doubt that this procedure is essential for the maintaining of pre-arranged programmes and was an important factor in maintaining the tight schedule for the reconstruction.

Ductility in High-temperature Rupture Tests

By J. Glen, B.Sc., A.R.C.S.T., F.I.M.

SYNOPSIS

Previous work has shown that various strain-age-hardening effects occur during high-temperature tensile testing, each associated with the presence of a particular alloying element. Corresponding to each of these effects there is a minimum in ductility at about the same temperature. It has also been shown that similar hardening effects occur during creep tests, resulting in what have been called transitions in creep rate. It has now been found that failure in long-duration rupture tests at high ductility may result from two mechanisms: a normal mechanism and an embrittling mechanism. If failure occurs by the embrittling mechanism it takes place during a transition in creep rate, showing that failure is associated with strain-age hardening. The results on several steels and other alloys are used to illustrate these phenomena, and a tentative hypothesis has been put forward to account for the results obtained. 1589

WHEN DEVELOPING AN ALLOY for use at high temperature it is not sufficient merely to show that the alloy has adequate creep and scaling resistance for the purpose intended. It is also necessary to ensure that the alloy will not be embrittled during service. This problem of high-temperature embrittlement has been the subject of investigation since 1928 when Bailey[1] reported the premature failure of boiler flange bolts made of a Ni–Cr steel. Other investigations have since shown that failure with low elongation in long-duration rupture tests is quite a common occurrence and that the fracture is intercrystalline. As such materials may give a good elongation in tests of shorter duration, it is obvious that prolonged testing may be necessary to prove that a particular material will have adequate ductility under extended service conditions.

In most cases it is very difficult to give an exact explanation of service failures because the material may have been subjected to periodic overloads due to an increase in either stress or temperature. It has been noted, however, that failures are often associated with minor surface defects. The possibility that such defects act as stress-raisers has led to the study of the effect of notches on the creep of metals and the relationship between ductility and notch sensitivity. The difficulty in interpreting the results will be appreciated, but Brown and Sachs[2] have concluded that if the elongation of a particular steel in a tensile rupture test falls below 5%, the steel will be sensitive to severe stress concentrations. There is thus some support for the widely held opinion that an elongation of 5% or more should be satisfactory for most applications.

From the above it is obvious that much effort would be saved if more was known about the mechanism of fracture. However, although some progress is being made towards a theoretical solution of the mechanism of failure of pure metals at high temperature, there is as yet no theory to explain the low elongations which can be obtained with complex alloys. In the present paper a tentative explanation of the effect of alloying elements on the elongation at fracture will be given. Before dealing with this subject, however, it is necessary to know something about the mechanism of failure of simple alloys. A brief review of the present state of knowledge is given below.

MODE OF FAILURE AT HIGH TEMPERATURE

At ordinary temperatures most metals and alloys fracture in a transcrystalline manner whatever the rate of straining. At high temperatures failure is usually transcrystalline if the metal is broken quickly, but with slow rates of straining failure may be wholly or partly intercrystalline. Under creep conditions failure is almost always intercrystalline.

Because of the intercrystalline nature of most failures at high temperature, considerable attention has been given to the study of the effect of stress on the behaviour of grain boundaries. At high temperatures the boundary zones behave in a quasi-viscous manner, so that when a stress is applied one crystal slides over another. It is difficult to see why this grain-boundary movement should lead to intercrystalline failure of a pure metal. On the application of a very small stress the boundaries flow under shear stress until the elastic strains set up in the crystals produce a system of forces in which there are no shear components along the grain boundaries. Under ordinary stresses, however, creep occurs within the body of the crystals so that the grain boundaries continue to flow in an attempt to relieve themselves of stress. Stress is thus concentrated at grain corners or on grain boundaries across the direction of the load. In a pure metal, however, it is to be expected that after such stresses have caused a little plastic deformation, the stress concentrations would be dissipated by recovery, recrystallization, or grain-boundary migration so that intercrystalline failure could not occur. In some of the tests reported in the literature it is therefore possible that the so-called pure metals used were not pure enough and that the intercrystalline failures resulted from the presence of impurities.

However, intercrystalline failure of itself is not of great practical importance. It is important only if it leads to failure after a low extension. This seldom, if ever, happens with a pure metal or simple solid solution. Failure with low elongation usually occurs only in rupture tests of long duration, the alloy being quite ductile in shorter tests. This cannot be due solely to grain-boundary flow, for with tests of still longer duration the elongation again increases.[3, 4, 5]

It can be concluded, therefore, that in alloys more than one factor must be taken into consideration to explain the results obtained.

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There seems little doubt that intercrystalline failure with a low elongation results when the relative strength of the body of the crystals compared with that of the grain-boundary regions exceeds a certain critical value. This idea was expressed many years ago by Bailey.[6] Such an effect, however, cannot occur unless some structural change takes place during testing, which augments the strength of the crystals to a greater extent than that of the boundary regions.

Grant[7] has put this idea in a somewhat different and more up-to-date way. He suggests that the properties of the grain boundaries are to a certain extent the properties of the grains, but that the imperfection of the grain boundary permits deformation processes to occur there preferentially at high temperature. The amount of deformation the grain-boundary regions can sustain depends on the extent of yielding, recovery, or accommodation by the grains.

The above concept implies that the stronger the grains, the greater the chance of grain-boundary failure. But the grains are not very strong in the initial stage of testing at high temperature since the initial creep rate is always large. The chance of failure will therefore increase with increasing duration of testing as the metal strain-hardens. It should also increase as other hardening influences come into play,

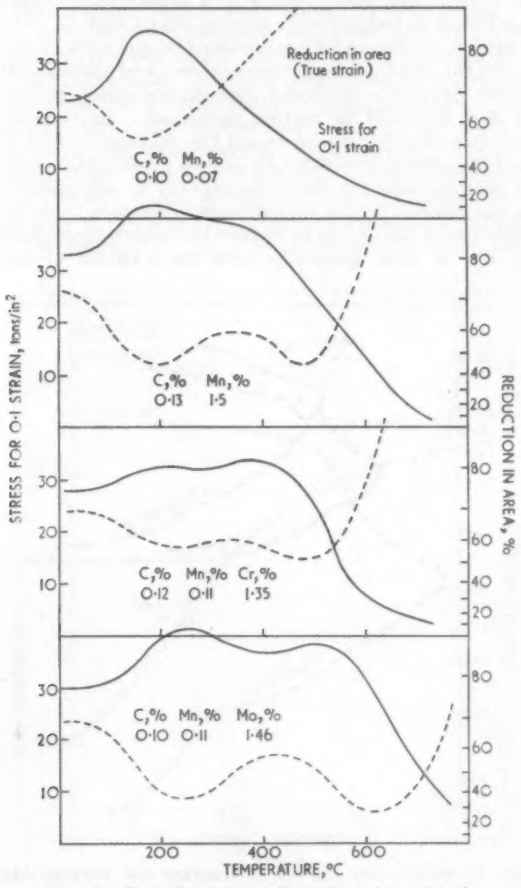

Fig. 1—Tensile properties of various steels

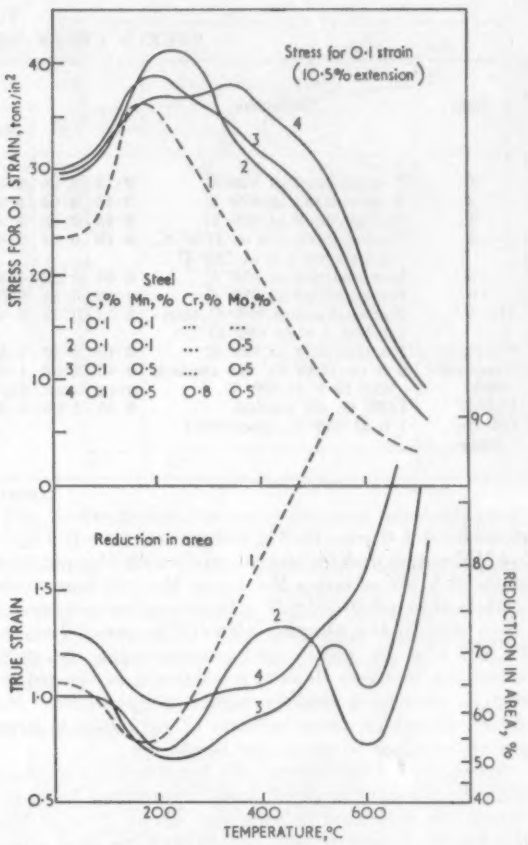

Fig. 2—Effect of alloying elements on tensile strength of 0·5%Mo steel

such as strain-age hardening and strain-induced precipitation. Conversely spheroidization or recrystallization should decrease the chance of grain-boundary failure. Thus the logical approach to the problem of brittleness should be the study of the change in strength of metals and alloys to see if there is any relationship between strength and ductility. A simple way of studying this aspect of the problem is by means of high-temperature tensile tests carried out with a very slow rate of straining.

High-temperature Tensile Tests

The author has already published the results of a large number of high-temperature tensile tests,[8, 9] showing the effect of most of the common alloying elements on the strength properties of normalized low-carbon steel. These results therefore need be only summarized here. It was found that for a simple Fe–C alloy one strain-age-hardening effect was obtained, giving a maximum in strength at about 200° C. If a little nitrogen was present (0·005%) this strain-age-hardening effect was intensified. With the addition of either Mn, Cr, Mo, W, or Cu, an additional strain-age-hardening effect was obtained at a temperature higher than 200° C, the actual temperature depending on the element used. Figure 1 shows the

Table I
STEELS CREEP-TESTED TO FRACTURE

Steel	Treatment	Composition, %												
		C	Si	Mn	Cr	Mo	V	Ti	Ni	Co	Al	W	Nb	Be
1	Normalized at 920° C	0·12	0·06	0·52	...	...	...	...	...	...	...	...	...	...
2	Normalized at 920° C	0·13	0·04	1·00	...	...	...	...	...	...	...	...	...	...
3	Normalized at 920° C	0·14	0·08	1·55	...	...	...	...	...	...	...	...	...	...
4	Normalized 1 h at 1150° C, tempered 5 h at 750° C	0·10	0·31	0·49	...	0·52	0·25	0·28	...	...	...	...	...	...
5	Normalized at 950° C	0·09	0·22	0·48	...	0·50	...	...	...	...	...	...	...	...
6	Normalized at 950° C	0·10	0·14	0·51	0·82	0·54	...	...	...	...	...	...	...	...
Mo–V*	Normalized at 975° C, tempered 5 h at 690° C	0·12	0·15	0·60	...	0·50	0·25	...	...	...	...	...	...	...
Carbon*	Normalized at 920° C	0·15	0·10	0·60	...	...	...	...	...	...	...	...	...	...
Nimonic* 80A	8 h at 1080° C, air cooled, and 16 h at 700° C	0·10 max.	1·00 max.	1·00 max.	0·20	...	...	2·30	75·0	2·0	1·0	...	...	...
G.18B*	1320° C, air cooled	0·40	1·00	0·80	0·13	2·00	...	...	0·13	10·0	...	2·50	3·00	...
Cu–Be alloy	1 h at 950° C, quenched	...	...	...	...	...	...	...	...	...	...	...	...	0·37

* Typical composition

stress for 0·1 strain (10·5% elongation) for a 0·1%C–0·1%Mn steel and for similar steels with the addition of about 1·5% of either Mn, Cr, or Mo. All four steels contained about 0·005%N. The second strain-ageing effect due to the alloying element is quite obvious. It will also be noted that corresponding to each maximum in stress there is a minimum in the reduction in area at a slightly higher temperature. No doubt, therefore, these minima of reduction in area are also related to strain-age hardening.

Microscopic examination of a large number of these tensile specimens showed some interesting features. When the reduction in area was about 25% or less the fractures were wholly intercrystalline, and intercrystalline cracks (particularly on the surface) could be detected at a considerable distance from the main fracture. At somewhat higher reductions in area, an apparently normal cup-and-cone fracture was obtained. However, examination revealed that the flat area at the centre of the broken test showed intercrystalline cracks, whereas at the sides failure was by shear. In other words, failure was initiated by intercrystalline cracks near the centre of the test-piece and changed to shear near the periphery. At still higher reductions in area it was difficult to determine the mode of failure, but it can be assumed that some degree of intercrystalline cracking was present.

In the above tests the expected relationship between strength and grain-boundary failure was obtained. Thus, as the grains were strengthened by strain-age hardening, the grain-boundary regions failed at a lower reduction in area. The relationship, however, is not a simple one since the results are modified if more than one alloying element is present. This is illustrated in Fig. 2 where the addition of 0·5%Mo to a 0·1%Mn steel is shown to increase the strength considerably. The strain-ageing effect of Mo is apparent at about 500° C. The addition of 0·5%Mn to the 0·5%Mo steel increases the strength slightly at 500° C. In this steel the strain-ageing effect of Mn is not very noticeable, but it is detectable between 300° and 400° C. Finally, if a further addition of 0·8%Cr is made, the strength at about 500° C is again increased. As Cr tends to reduce the strength at 200° C its own strain-ageing effect is made more obvious, giving a maximum in stress at about 350° C.

As is also shown in Fig. 2 the addition of 0·5%Mo to a 0·1%Mn steel results in a pronounced second minimum in reduction in area at about 600° C. The addition of Mn and Cr increases the strength of the 0·5%Mo steel at high temperature, and therefore it might have been expected that the reduction in area at 600° C would be further decreased. In fact the addition of 0·5%Mn increased the ductility at 600° C and the addition of 0·8%Cr caused a further increase, so that the effect of Mo is shown only by an inflexion in the curve. It can be concluded therefore that the addition of Mn or Cr can reduce the embrittling effect of Mo, or more generally that the addition of one

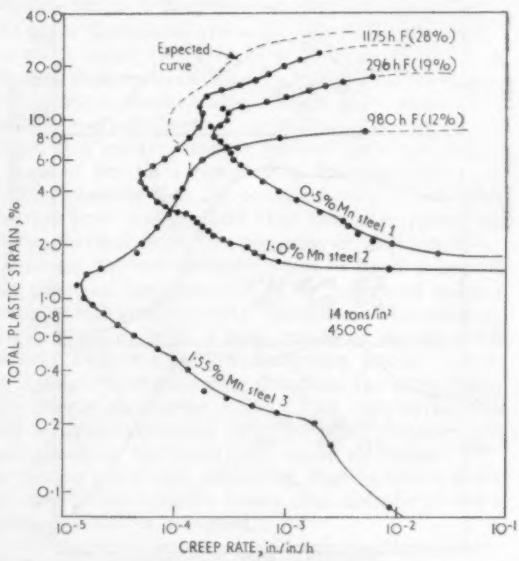

Fig. 3—Strain rate curves to fracture for various Mn steels

alloying element may modify the embrittling effect of another alloying element.

CREEP TESTS TO FRACTURE

In other papers[10, 11] the author has shown that the strain-age-hardening phenomena found in high-temperature tensile tests are also detectable during creep tests on the same steels. In the creep tests strain-ageing resulted in what were called transitions in creep rate. These took the form of rapid decelerations in creep rate over an interval of time. It was also found that the number of transitions in a creep curve was the same as the number of strain-ageing effects obtained in high-temperature tensile tests on the same steel. Thus in an ordinary C–Mn steel three transitions in creep rate are obtained which are due to N, C, and Mn. These transitions are shown up clearly by plotting the creep data in the form of log strain/log creep-rate curves.

Since strain-ageing effects resulted in low reductions in area in the high-temperature tensile tests it thus seems possible that low elongations in long-duration rupture tests are also related to strain-ageing or strain-induced precipitation. If this assumption is correct then the low elongations in rupture tests must be related in some way to the transitions in creep rate obtained in the creep curves of such alloys.

Unfortunately, relatively few creep tests are carried out at stresses which would lead to fracture in a reasonable time. Even in such cases as have been reported the extensometer is usually removed well before the onset of fracture. In rupture tests to fracture no extensometer is employed, the only information obtained being the time and elongation at fracture. A few strain/rate curves to fracture were shown in the papers to which reference has already been made.[10, 11] A few other results have been

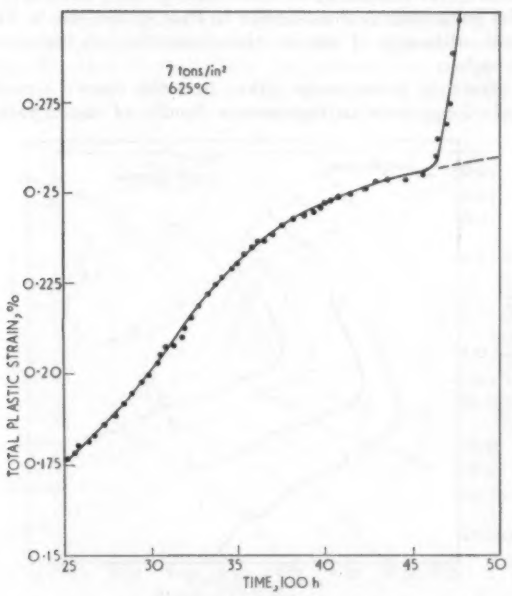

Fig. 4—Part of creep curve for Mo–V–Ti steel 4

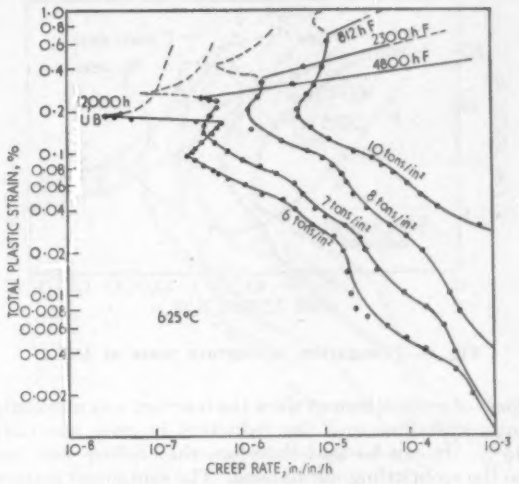

Fig. 5—Strain/rate curves to fracture, Mo–V–Ti steel 4

obtained. Of particular interest are some creep tests made on a steel which, because of its treatment, proved to be very brittle, failure occurring after less than 1% extension. Details of these materials in the order in which they will be considered are shown in Table I.

C–Mn Steels

The strain/rate curves to rupture on steels 1 and 2 at 450° C and various stresses are shown in other papers[10, 11] and need not therefore be reproduced. It can be stated, however, that whereas the 1%Mn steel 2 fractured with an elongation of about 30%, the 0·5%Mn steel 1 failed in two tests at about 12% elongation. In no case has the failure any apparent connection with a transition in creep rate. The lower elongation of steel 1 is not a sign of embrittlement. It is simply due to the lower work-hardening capacity of this steel. In fact, if the ductility is taken to be the reduction in area, the low-manganese steel is the better having a reduction in area of about 50% compared with about 40% for the higher-manganese steel. In both cases, therefore, fracture can be taken to be the result of what will be called the normal mechanism. Although this mechanism is still in dispute it must be connected with the build-up of stress concentrations due to grain-boundary flow. These will increase with increasing strain since in this case, and unlike that of pure metals, the recrystallization temperature is quite high.

If, however, the above steels are compared with the 1·55%Mn steel 3 a different phenomenon makes its appearance. This is apparent from Fig. 3 showing strain/rate curves to fracture at a stress of 14 tons/in² and a temperature of 450° C. From the previous argument it might be expected that the 1·55%Mn steel would fail with a greater extension than the 1%Mn steel. It was also to be expected that this steel would show a longer time to fracture. In fact the extension was only 12% and the time to fracture was less than that of the 1%Mn steel. This low elongation and short time to fracture are due to some

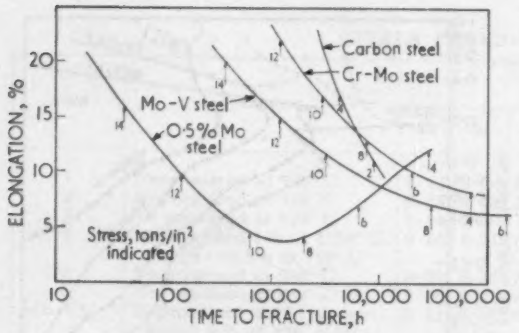

Fig. 6—Elongation in rupture tests at 550° C

form of embrittlement since the fracture was markedly intercrystalline and the reduction in area was only 15%. It can be said therefore that failure was due to the embrittling mechanism. The significant feature of the result on steel 3 is that the strain/rate curve does not show a transition due to Mn, but fractures quickly at about the strain where the Mn transition should just be beginning. The expected curve showing this transition is shown by the pecked curve in Fig. 3. It can be concluded, therefore, that when a transition in creep rate begins, the chance of intercrystalline failure increases. As the transition in creep rate nears completion the chance of failure decreases and the alloy may extend considerably before failure eventually occurs by the normal mechanism.

Mo–V–Ti Steel

Another example of this type of failure was given by a series of creep tests on the Mo–V–Ti steel 4. This steel was heat-treated by holding at 1150° C for 1 h before air cooling. It was then tempered for 5 h at 750° C. Though this treatment gave the maximum creep-resistance it was found that the structure had coarsened considerably and the steel was brittle. (It was subsequently found that 10 min at 1150° C was sufficient to prevent this grain coarsening and that a better ductility was obtained without much sacrifice of the creep resistance). Figure 4 shows part of the creep-test curve on this steel at a stress of 7 tons/in² and a temperature of 625° C. At 2500 h the creep rate was accelerating, but at about 3500 h and at a strain of 0·225% a marked transition in creep rate began and the creep rate decreased rapidly. At 4600 h, however, intercrystalline failure began, resulting in an abrupt acceleration in creep rate. Fracture took place at 4800 h with very little elongation or reduction in area. Thus, in this case also, fracture took place by the embrittling mechanism near the beginning of a transition in creep rate.

The strain/rate curve of the above test and of tests at 6, 8, and 10 tons/in² are shown in Fig. 5. The test at 6 tons/in² was discontinued after 12,000 h. It will be seen, however, that at this stress the steel had survived the pronounced transition in creep rate without fracture and it may be that the elongation would have been appreciable. At a stress of 7 tons/in² the transition should have been nearly as pronounced as at 6 tons/in². The probable curve is shown by a pecked line. However, because of intercrystalline failure there was an abrupt increase in creep rate as was indicated in Fig. 4. Similarly at a stress of 8–10 tons/in² there is an abrupt change in creep rate due to intercrystalline failure. In these cases, however, it occurs nearer the beginning of the transition though at a higher strain because the transition begins at a higher strain with increasing stress.

0·5%Mo and Cr–Mo Steels

Although creep tests to fracture were not carried out on the 0·5%Mo steel 5 and the 1% Cr–0·5%Mo steel 6, some conclusions can be made from the available data. From previous work[4] the elongation at fracture during long-duration tests at 550° C was known. From these tests the elongation/log time to fracture curves shown in Fig. 6 were obtained. The stresses to cause fracture have been indicated on these curves. It will be noted that a minimum in ductility occurs after about 1000 h with the 0·5%Mo steel, but that with the Cr–Mo steel the elongation is still decreasing after 70,000 h of test. It will also be noted that the minimum elongation of the former steel is about 3% whereas after 70,000 h the elongation of the Cr–Mo steel is still about 8%.

From the available creep curves and from the known times and elongation to fracture it was possible to make an estimate of the shape and position of a series of strain/rate curves to fracture at 550° C for the 0·5%Mo steel: this is shown in Fig. 7. The position at which the transition due to Mo begins is indicated by a chain-dotted curve. It seems clear that at stresses of 14 tons/in² down to 9 tons/in² failure occurs by the embrittling mechanism. The elongation at the same time falls to 3% because the transition begins at a lower strain, the lower the testing stress. At a stress of 8 tons/in² the steel survives the beginning of the transition without failure and breaks at an extension greater than 3%. The behaviour is thus similar to that of the Mo–V–Ti steel, although of course, the elongation at fracture is higher.

Similarly from creep curves and the known times and elongations to fracture, a family of strain/rate

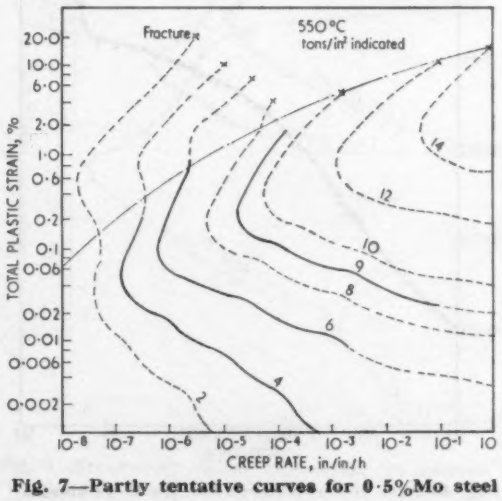

Fig. 7—Partly tentative curves for 0·5%Mo steel 5

curves can also be constructed for the Cr–Mo steel: this is shown in Fig. 8. In this case fracture at or near the beginning of the Mo transition occurs at stresses of 12 tons/in² or higher. Thus, if this steel had behaved like the 0·5%Mo steel a minimum in elongation would have been obtained at an elongation of about 20%, at a stress of 12 tons/in², and in a time of 1000 h. In fact, of course, the elongation of the Cr–Mo steel continues to fall slowly as the stress of testing is reduced. Some other factor must therefore be introduced to account for the difference between these steels, and this is discussed later.

Other Alloys

Creep-test data were obtained for Nimonic 80A[12] and the derived strain/rate curves are shown in Fig. 9. As the stress decreases from 16 to 10 tons/in² the elongation at fracture decreases. At a stress of 7 tons/in² the elongation increases and the material shows a definite transition in creep rate, beginning at about 0·3% strain. It seems probable, therefore, that at the higher stresses intercrystalline failure has occurred near the beginning of this transition. If failure could have been avoided a more pronounced transition in creep rate would have been obtained at these stresses, as is suggested by the pecked curves.

The results on alloy G.18B[13] shown in Fig. 10 are also interesting. At a stress of 6 tons/in² and a temperature of 850° C fracture took place at about 10% elongation and seems to occur just at the beginning of a transition. At 750° C, on the other hand, the test had survived the transition without failure, which took place eventually at about 15% elongation. It is probable that the elongation will increase at still lower temperatures, as is suggested by the pecked curves in Fig. 10. The results on this alloy thus support the conclusions already made.

McLean and Farmer[14] have carried out creep tests on a variety of metals. One test at a stress of 3·5 tons/in² and a temperature of 400° C was made on a Cu–Be alloy from which the strain/rate curve in Fig. 11 was obtained. Examination of this curve shows that there are two transitions in creep rate,

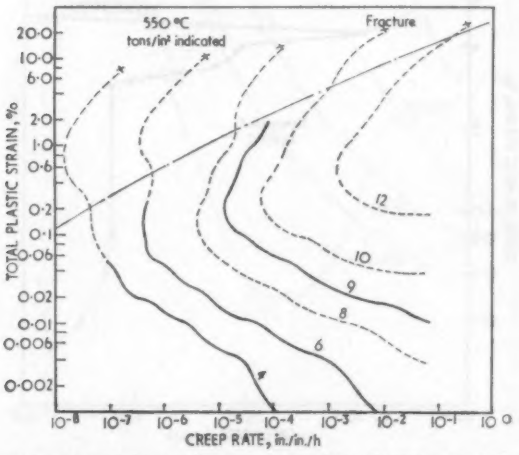

Fig. 8—Partly tentative curves for Cr–Mo steel 6

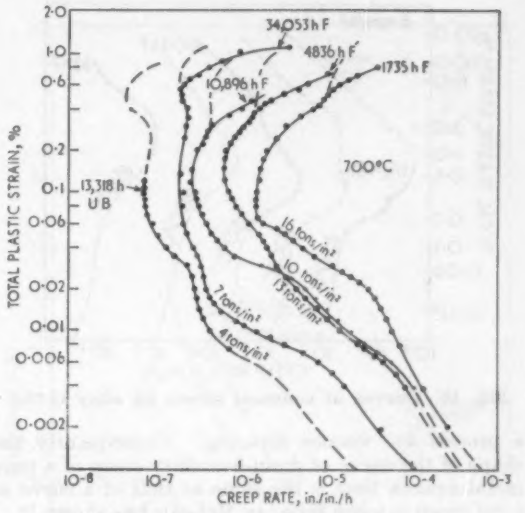

Fig. 9—Strain/rate curves at various stresses on Nimonic 80A

one after about 3% elongation and a second after about 4% elongation. This second transition might, of course, be due to experimental error since there are relatively few points defining the creep curve. However, there seems no doubt that fracture is initiated during a transition in creep rate. As before, it is probable that this second transition would be more pronounced if fracture could have been prevented. In view of the simplicity of this alloy it would appear to be an ideal one for further investigation of this problem.

TENTATIVE HYPOTHESIS

From the above results it is clear that two important factors must be included in any hypothesis dealing with low elongation in rupture tests. First, a satisfactory reason must be given to explain intercrystalline failure during a transition in creep rate. Secondly, the hypothesis should explain why the presence of one alloying element may minimize the embrittling effect of another alloying element. Before attempting any such explanation it is necessary first of all to obtain some idea of the mechanism of grain-boundary creep. McLean[15] has shown that creep of polycrystalline metals occurs by dislocation migration in the grains, resulting in slip and sub-grain tilting, as well as by grain-boundary shearing. He also shows that, for a given stress, the ratio of the fraction of the total plastic strain arising from grain-boundary shear to the total plastic strain is constant.

Fazen, Sherby, and Dorn[16] have confirmed this finding. Furthermore Dorn[17] has shown that this ratio remains constant for a given stress independent of testing temperature, and concludes that the same activation energy and the same creep law hold for 'grain-boundary shear' as apply to the total creep of the pure metal. This, Dorn suggests, means that grain-boundary shearing can be attributed to localized crystallographic mechanisms of deformation in the vicinity of the grain boundaries rather than to such

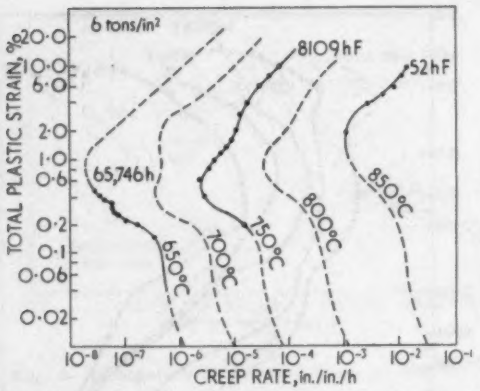

Fig. 10—Curves at constant stress on alloy G.18B

a process as 'viscous shearing.' Consequently the shape of the curve of grain-boundary creep of a pure metal against time is the same as that of a curve of total creep against time, as McLean has shown.[14]

The actual creep rate is, however, faster in the grain-boundary region so that, with increasing time of test, the stress concentrations at grain corners or on grain boundaries across the direction of load tend to increase and intercrystalline failure may eventually result by the normal mechanism. In complex alloys failure may occur in the same way, but the occurrence of a transition may cause another type of failure in a manner somewhat as given below.

Since Dorn's work suggests that the same creep law applies to grain-boundary creep as to total creep of a pure metal it is a reasonable assumption that the grain-boundary creep curve of a complex alloy will also have the same general shape as the ordinary creep curve of the alloy, that is, it will show the same number of transitions in creep rate. If the two creep curves are considered, then initially they behave like a pure metal. When a transition in creep rate occurs the ordinary creep curve slows down rapidly as the strain-ageing constituent precipitates in the dislocations. If the rate of diffusion of this constituent is high, precipitation in the grain-boundary regions will be just as rapid as in the crystals themselves so that the transition in the grain-boundary creep curve will occur at the same time as that of the ordinary creep curve.

If, however, a transition occurs which depends on the diffusion of an alloying element such as Mo, then conditions are rather different. In the body of the crystals the alloying element does not have far to travel to cause precipitation within a dislocation. Migration to the grain-boundary zones, however, requires more time. Thus, in this case the transition in grain-boundary creep rate will be delayed compared to the ordinary transition. As a result, when a transition begins in the crystals, the grain-boundary regions become relatively much weaker than the crystals so that the chance of intercrystalline failure increases. In this case failure would result from the embrittling mechanism. If, however, the stress is low enough and failure does not occur the grain-boundary zones become stronger since the alloying element has time to diffuse to the boundaries and a transition in boundary creep rate occurs. Thus, when failure eventually takes place it is by the normal mechanism.

A delay in the transition at the grain boundary could also explain the effect of Cr on 0·5% Mo steel. The transition due to Mo begins when that due to Cr is nearing completion. Thus, when the transition due to Mo begins in the crystals, the delayed transition in creep rate due to Cr may still be taking place in the grain-boundary region. As a result the grain-boundary zones do not become relatively much weaker than the body of the crystals, so that the chance of failure by the embrittling mechanism is decreased.

No useful purpose would be served by attempting to extend the above hypothesis to any greater length. Direct proof of any such effect would be given by estimating the grain-boundary creep of alloys by the methods used by McLean for pure metal. If the ratio of grain-boundary creep to total creep were measured throughout a test, the variation of this ratio could be used to prove or disprove the above hypothesis.

FAILURE IN SERVICE

If it is accepted that stress concentrations resulting from minor surface defects are minimized by local creep then it must be concluded that these stress concentrations relax rapidly when the component is put into service, since the creep rate is rapid in the initial stages. Thus, if a material is notch sensitive and liable to failure it must develop its brittleness in a reasonable time, otherwise the stress will have relaxed to a low level before the brittleness has had time to develop. In a notched rupture test the stress does not relax rapidly, so that notch sensitivity of itself is not a direct measure of the possible behaviour in service. Ordinary 0·5%Mo steel is known to be notch sensitive and, as shown in Fig. 9, it requires only about 1000 h at 550° C for the development of maximum brittleness. A Mo–V steel normalized from a high temperature and which has not been tempered can also become brittle as shown by Tapsell,[3] but in

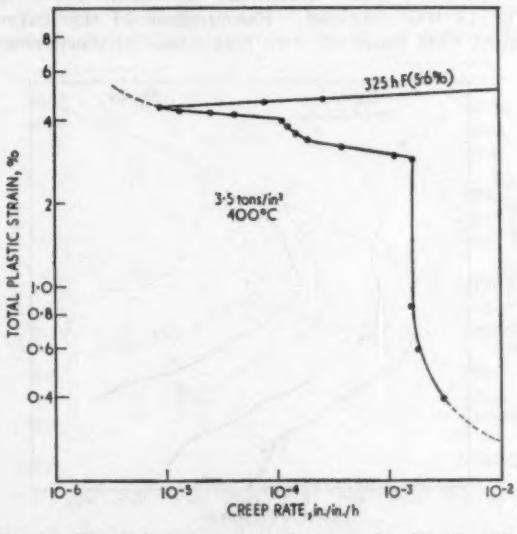

Fig. 11—Strain/rate curve to fracture for Cu–Be alloy

this case it required about 10,000 h at 550° C to develop the maximum brittleness. It is not, therefore, very surprising to find that the same material was quite insensitive to notches.[18] It would appear, therefore, that if the brittleness takes a long time to develop it may not be so deleterious as is generally supposed. Although the above statement is reassuring, prolonged testing must be carried out on each material to show that brittleness does not develop too quickly. However, as a safeguard against any chance of failure it is necessary to ensure that failure during a transition in creep rate is not liable to occur during the 10- or 20-year life of the plant.

In this paper it has been shown that failure in long-duration rupture tests at high temperature can occur by two mechanisms: the normal mechanism and the embrittling mechanism. Dorn has stated[17] that the strain damage due to grain-boundary flow is concentrated more and more in the vicinity of the boundaries as the stress of testing is reduced because the fraction of the total creep strain arising from grain-boundary creep increases as the stress is reduced. It is to be expected, therefore, that when the normal mechanism holds, the elongation at fracture should decrease as the stress is reduced. This tendency will be reversed, however, if the structure of the steel changes because of rapid recovery or recrystallization, that is, the elongation should increase with decreasing stress. If, however, the embrittling mechanism comes into play the elongation should fall below the elongation/stress curve of failu the normal mechanism. With decreasing stress, however, as shown in Fig. 7, a material can survive the transition without failure.

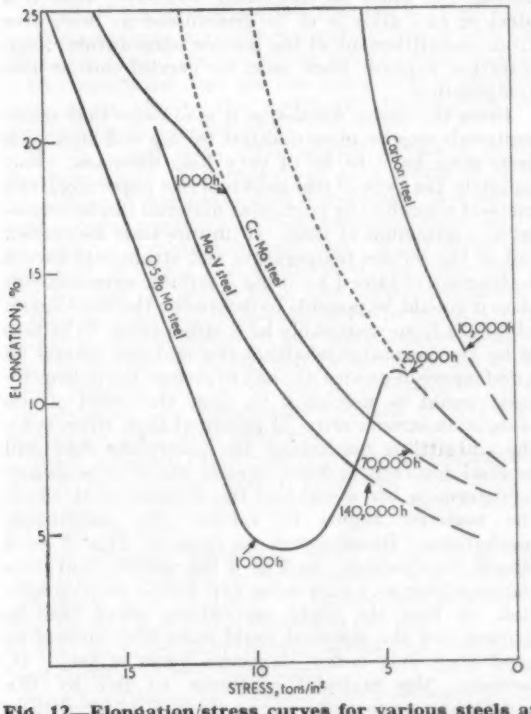

Fig. 12—Elongation/stress curves for various steels at 550° C

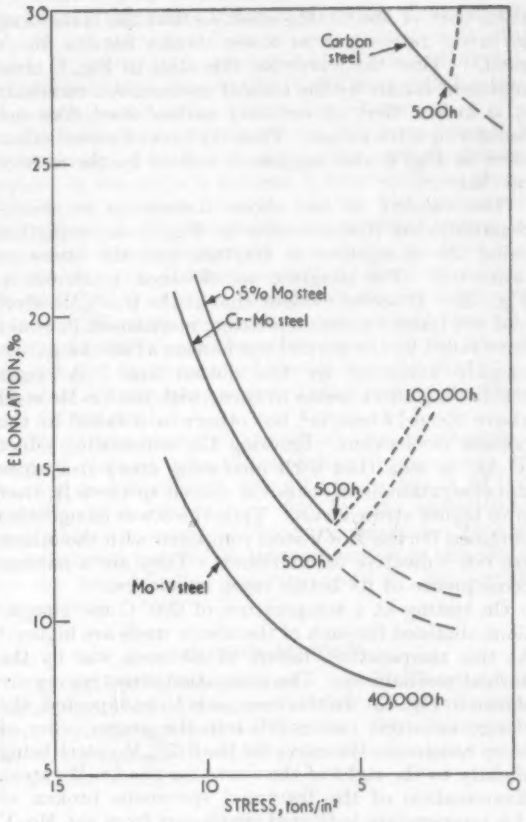

Fig. 13—Elongation/stress curves for various steels at 600° C

Thus, the elongation should increase with decreasing stress until it meets the normal curve. With further decrease in stress the elongation should again fall.

In Fig. 6 the elongation/time to fracture curves for various steels at 550° C are shown. With the exception of the carbon steel these results are the average of data on about ten casts of each steel. Full details were given in a previous paper,[4] so for simplicity the experimental points have not been included. The curve for the carbon steel is based on tests by the author at 575° C and results published by White[19] of tests at 538° C.

Comparing the elongation curve for the 0·5%Mo steel in Fig. 6 with the strain/rate curves to fracture in Fig. 7 shows that down to about 9 tons/in² this steel fails by the embrittling mechanism. At lower stresses it begins to survive the transition and the elongation increases. At about 4 tons/in² the curve seems to be flattening off. It would, however, require tests approaching 100,000 h duration to show that the elongation again begins to fall with decreasing stress.

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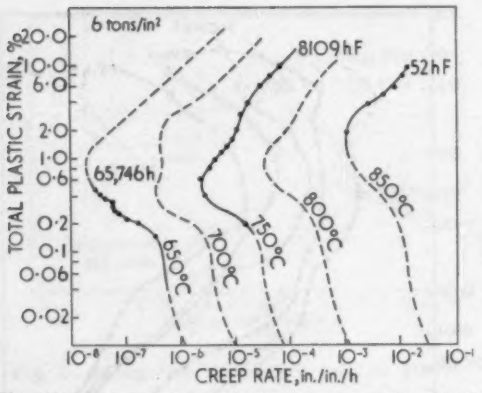

Fig. 10—Curves at constant stress on alloy G.18B

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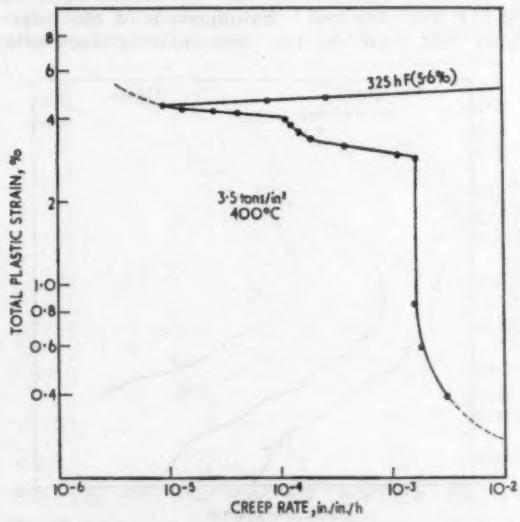

Fig. 11—Strain/rate curve to fracture for Cu–Be alloy

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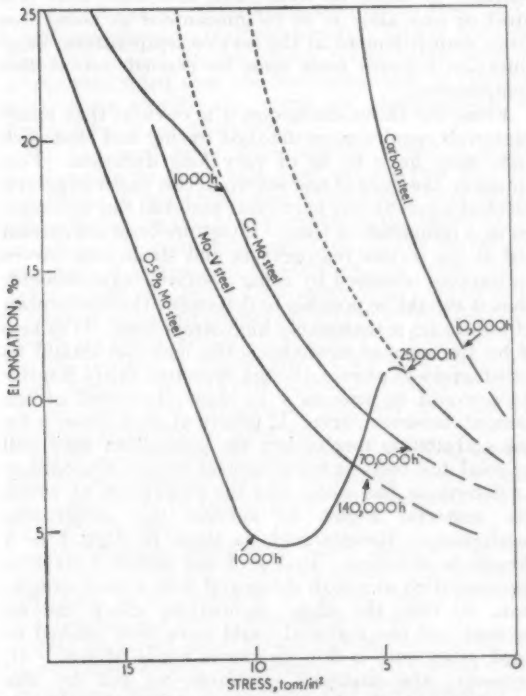

Fig. 12—Elongation/stress curves for various steels at 550° C

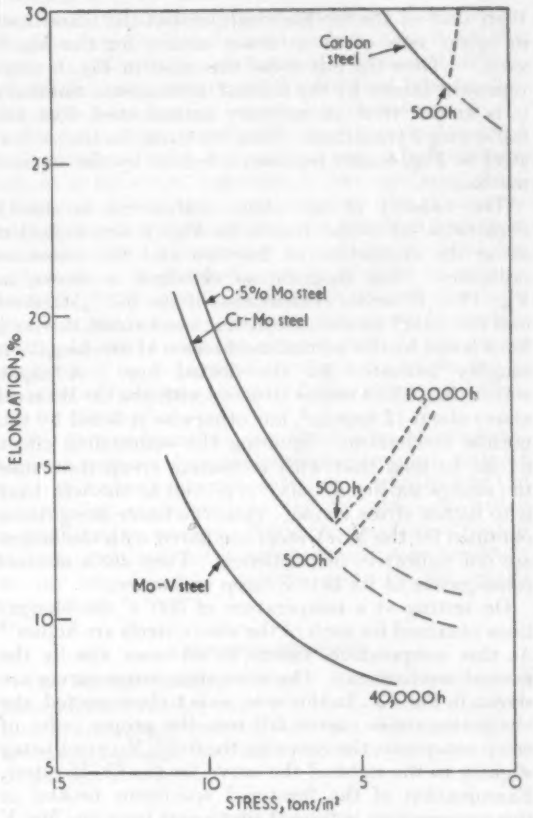

Fig. 13—Elongation/stress curves for various steels at 600° C

Thus, the elongation should increase with decreasing stress until it meets the normal curve. With further decrease in stress the elongation should again fall.

In Fig. 6 the elongation/time to fracture curves for various steels at 550° C are shown. With the exception of the carbon steel these results are the average of data on about ten casts of each steel. Full details were given in a previous paper,[4] so for simplicity the experimental points have not been included. The curve for the carbon steel is based on tests by the author at 575° C and results published by White[19] of tests at 538° C.

Comparing the elongation curve for the 0·5%Mo steel in Fig. 6 with the strain/rate curves to fracture in Fig. 7 shows that down to about 9 tons/in² this steel fails by the embrittling mechanism. At lower stresses it begins to survive the transition and the elongation increases. At about 4 tons/in² the curve seems to be flattening off. It would, however, require tests approaching 100,000 h duration to show that the elongation again begins to fall with decreasing stress.

The Cr–Mo steel, on the other hand (Figs. 6 and 8), survives the transition below about 12 tons/in² and thereafter with decreasing stress the elongation falls slowly, failure occurring by the normal mechanism. The creep rate of the Mo–V steel is much slower even

than that of the Cr–Mo steel, so that the transitions in creep rate occur at lower strains for the Mo–V steel.[11] Thus the curve for this steel in Fig. 6 must represent failure by the normal mechanism. Similarly it is known that an ordinary carbon steel does not fail during a transition. Thus the curve for the carbon steel in Fig. 6 also represents failure by the normal mechanism.

The validity of the above statements is clearly demonstrated if the results in Fig. 6 are replotted using the elongation at fracture and the stress as ordinates. The diagram so obtained is shown in Fig. 12. It seems evident that if the 0·5%Mo steel had not failed by the embrittling mechanism it would have failed by the normal mechanism at an elongation roughly indicated by the dotted line. A slight embrittling effect seems to occur with the Cr–Mo steel above about 12 tons/in², but otherwise it failed by the normal mechanism. Ignoring the embrittling effect it can be seen that with increasing creep resistance the elongation/stress curve is moved to the left, that is to higher stress levels. Thus the lower elongations obtained for the Mo–V steel compared with the others are not indicative of brittleness. They are a natural consequence of its better creep resistance.

On testing at a temperature of 600° C the elongations obtained for each of the above steels are higher.[4] At this temperature, failure in all cases was by the normal mechanism. The elongation/stress curves are shown in Fig. 13. In this case, as is to be expected, the elongation/stress curves fall into the proper order of creep resistance, the curve for the 0·5%Mo steel being slightly to the right of the curve for the Cr–Mo steel. Examination of the fractured specimens broken at this temperature indicated that apart from the Mo–V steel recrystallization occurred in the tests at the lowest stress. Thus, as is shown by the dotted lines, the elongation increased as the stress decreased below a certain value. In this case the increasing elongation does not occur for the same reason as was the case for the 0·5%Mo steel at 550° C. It is simply because of recrystallization.

The 0·5%Mo type of steel has given considerable trouble in the form of intercrystalline failures in service. However, as is shown above, this steel is unique in that its behaviour is quite different from that of the other three steels considered. It just so happens that 0·5%Mo steel is liable to fail by the embrittling mechanism at the normal operating temperatures. For this reason alone, therefore, it is not to be expected that the same trouble will be experienced with the other three types of steel.

What, however, is the chance of failure for the other steels, and in particular the Mo–V steel? Suppose this steel has been in service at a stress of 6 tons/in² and a temperature of 550° C for a period of 100,000 h. From Fig. 12 it is obvious that under these conditions the steel is approaching the time and elongation at which it will fail by the normal mechanism. If at this stage a notch is introduced, a stress concentration of, say, 10 tons/in² could be obtained. Because of this high stress the creep rate locally will increase, but since equilibrium has been disturbed it is to be expected that the sub-microstructure will rapidly change so that the fraction of the total plastic strain arising from grain-boundary creep decreases and the 'strain damage' at the boundaries is spread over a wider region. Thus, if this stress were to be maintained, failure would not occur at about 7% elongation, but would occur after 12% elongation as indicated in Fig. 12 for this stress. However, this stress is not maintained but relaxes rapidly until it approaches the working stress, in this case 6 tons/in². To relax 10 tons/in² to 6 tons/in² requires only a local extension of about 0·05%. Thus there does not appear to be much chance of failure even under the quite severe conditions suggested.

The above data show that the problem is quite complex and that a large amount of long-duration testing is necessary to obtain a true assessment of ductility. For this reason comparatively short-duration rupture tests may suggest that a particular material is the worst of a series of materials, although it might even be the best under service conditions. What is more important, however, is that such tests may show a material to be good although it may be seriously embrittled under service conditions. Furthermore, even long-duration rupture tests may be misleading if they are carried out at too high a temperature. For example, if tests on the 0·5%Mo steel had not been carried out at 550° C it would have been concluded from the results at 600° C that this steel was better than either the Cr–Mo steel or the Mo–V steel. The reason for this, of course, is that if failure does not occur during a transition, that is by the embrittling mechanism, then failure will occur by the normal mechanism at an elongation related approximately to the creep resistance *at the temperature of testing*. It must be concluded, therefore, that if a steel or any alloy is to be guaranteed as being free from embrittlement at the service temperature, long-duration rupture tests *must* be carried out at this temperature.

From the above discussion it is obvious that many materials require more detailed testing and that such tests may have to be of very long duration. Fortunately the type of test shown in this paper suggest a method whereby any particular material can be assessed in a minimum of time. If rupture tests are carried out at the service temperature and strain/rate curves to fracture obtained by using a suitable extensometer then it should be possible to determine the mechanism of failure from reasonably high-stress tests. If failure is by the normal mechanism the material should be satisfactory in service, though of course, fairly lengthy tests would be necessary to show the trend of the elongation/stress curve. If failure at high stress is by the embrittling mechanism the elongation may still be good, but tests at lower stresses would be necessary to determine the stress and the elongation at which the material begins to survive the embrittling mechanism. Results such as those in Figs. 7 or 8 should be obtained. In Fig. 8 the material survives the transition at a high stress and with a good elongation, so that the slight embrittling effect can be ignored and the material could have been classed as good after only a few thousand hours of test. If, however, the material continues to fail by the embrittling mechanism as the stress is reduced then it might be necessary to carry out very lengthy tests

to determine the minimum elongation liable to be obtained at the service temperature. The trend, of course, would be shown by the strain/rate curves, so that even in this case a decision regarding the suitability of the material could be made in a reasonably short time.

SUMMARY AND CONCLUSIONS

(1) Even though simple alloys may fail with an intercrystalline fracture in long-duration rupture tests at high temperatures the ductility is usually high. Thus, in more complex alloys where failure in long-duration tests may take place with a low extension, it was considered that some other factor must have been introduced.

(2) This factor must relate to some structural change since if a low elongation is obtained after a certain time at a particular temperature the elongation again increases in still longer testing times.

(3) It was shown that the chance of intercrystalline failure should increase as the metal hardens because of either strain hardening, strain-age hardening, or strain-induced precipitation.

(4) From high-temperature tensile tests it was shown that the addition of various alloying elements to steel resulted in strain-age hardening at high temperature and that there were corresponding minima in the curves of reduction in area against temperature. These results thus supported conclusion (3) above.

(5) It was also shown that the addition of Mn and Cr minimized the embrittling effect of 0·5%Mo in the high-temperature tensile tests, despite the fact that these elements increased the strength of the Mo steel.

(6) Since the elements which resulted in strain-age-hardening effects in high-temperature tensile tests on steel also caused similar effects during creep testing, it was concluded that the low elongation in rupture tests might also be the result of strain-ageing or strain-induced precipitation.

(7) In creep tests strain-ageing causes a rapid deceleration in creep rate over an interval of time (transition in creep rate) and it was found that failure with a low elongation always occurs at the beginning of or during a transition in creep rate. If the elongation was high it might also result from the same cause, but it could also result from some other mechanism.

(8) Log strain/log creep-rate curves to fracture were shown for the following alloys: several steels of varying Mn content, 0·5%Mo and Cr–Mo steel, Mo–V–Ti steel, Nimonic 80A, G.18B, and a Cu–0·37%Be alloy. In all cases low elongations resulted from failure during a transition in creep rate.

(9) A tentative hypothesis is put forward to explain the results obtained and in particular to show why the addition of Cr can improve the rupture ductility of 0·5%Mo steel.

(10) Although brittleness, which takes a long time to develop, may not be so deleterious as is generally supposed, it is advisable to ensure that a material will not fail in a brittle manner in service.

(11) As stated in (7) above, failure may result from one or other of two mechanisms. It may occur either by an embrittling mechanism, that is during a transition in creep rate, or by the normal mechanism which is related to grain-boundary flow and the build-up of stresses on transverse grain boundaries. From long-duration rupture test data on carbon steel, 0·5%Mo steel, 1%Cr–0·5%Mo steel and Mo–V steel at 550° C it is shown that only the 0·5%Mo steel fails by the embrittling mechanism with a low elongation.

(12) Because, as Dorn has shown,[17] ' strain damage ' is concentrated more and more in the grain-boundary regions as the stress is reduced it was concluded that, if failure is by the normal mechanism, the elongation at fracture should decrease as the stress of testing is reduced. This relationship was shown to hold for carbon steel, Cr–Mo steel, and Mo–V steel on testing at 550° C. At this temperature it should also hold for 0·5%Mo steel at stresses below about 4 tons/in².

(13) At 600° C, on the other hand, all the above steels failed by the normal mechanism and the 0·5% Mo steel actually gave slightly better elongations than the Cr–Mo steel.

(14) It was therefore concluded that short-period rupture tests or even long-duration rupture tests at too high a temperature may give no indication of the liability of a material to fail by the embrittling mechanism in service. Thus, to guarantee that a material will not fail in this manner, it is necessary to do long-duration rupture tests *at the service temperature*.

Acknowledgments

The author wishes to thank Mr. W. Barr, Chief Metallurgist and Director of Colvilles Ltd., for continued encouragement and advice. He also wishes to thank him and his fellow directors for permission to publish this paper.

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Continuous Casting

By G. C. Olson

AT ATLAS STEELS LTD., WELLAND, ONTARIO, CANADA

SYNOPSIS

This paper traces the commercial development of the continuous-casting machine as it has taken place at Atlas Steels Ltd., Welland, Ontario, Canada, from the first successful cast in January 1954 to the present time. Basic differences between continuous and conventional casting are reviewed and the installation and operational features of the machine are explained. Many of the development problems encountered are also outlined. Austenitic stainless steels for sheet, strip, bar and wire, some tool and alloy constructional steels for bar and wire, as well as low-alloy billets for extrusion of seamless pipe, are now in regular production on a favourable cost basis. The economics of continuous casting compared with conventional ingot casting are considered, and the author concludes that the savings attained by continuous casting must be sufficiently great to give a reasonable return on the substantial capital investment, although this investment may be less than is required for conventional ingot processing. It is hoped to realize maximum savings by concentrating attention on: (*a*) elimination of processing operations, (*b*) casting of higher alloyed steels to give greater yield savings, and (*c*) reduction of casting cost and raising casting margin by increasing volume cast. 1587

INTRODUCTION

THE IDEA of continuous casting of metals has captured the attention and imagination of many inventors; numerous patents have been issued, but only a few of these processes have been workable. One of the most successful casting techniques was developed during the early 1930's in Germany, and is now known as the Junghans–Rossi process. The original technique developed by Junghans was applied to brass casting, but it was not until 1949 that the first successful attempts were made to apply the process to the casting of steel.

The most interesting consideration of the continuous-casting process, especially in this era of high equipment costs and break-even points, is the possibility of increasing output and yield with a minimum of investment. With this thought in mind the author's company decided to install a continuous-casting machine, designed primarily to produce semi-finished products (slabs and billets) directly from the liquid metal.

The resultant economies anticipated were:

(i) A substantial increase in yield, i.e. no butt loss, and only a very little top and bottom discard from an entire heat

(ii) Elimination of many of the pouring-pit costs such as moulds, hot tops, handling equipment, etc.

(iii) Elimination of some ingot processing operations (or reduction in costs of these operations) to arrive at a similar-sized product. Table I shows a broad comparison of processing steps.

(iv) The possibility of producing directly from the machine a cast product suitable for shipping without further processing, such as cast billets to be used directly for piercing, re-rolling, or forging.

After a thorough study of the economics involved, the decision was made to install a machine. It then became necessary to lay out a planned development programme, so a survey was made of the company's grades and end products to determine the most effective use of the equipment. This in turn led to consideration of the most desirable mould sizes to install for the initial operating programme.

The sizes decided upon were as follows:

(i) 5½ in. × 21½ in., for stainless flat products (sheet and strip).

(ii) 5½ in. × 7½ in., for higher alloyed steels such as silicon valve steels, and also intermediate bar products of any grade. This size, like the 5½ in. × 21½ in., was not designed to by-pass the blooming mill, but only to by-pass the ingot stage and provide resultant yield savings.

(iii) 4½ in. × 4½ in. square, primarily for high-alloy tool steels (such as high-speed steels), but also for coils and small bar products of any grade. This size was designed to by-pass both the ingot stage and the cogging stage (either blooming mill or forge) and also to show considerable yield savings.

Processing of the 5½ in. × 21½ in. size to sheet and strip, for which the machine was primarily designed, was set up as shown in Tables II and III.

As the initial programme with these three mould sizes progressed, it became evident that some change in sizes would have to be made to obtain either better quality or higher savings or both. As time went on, it also became apparent that the company would have to consider multiple stranding on the smaller sizes, especially the square sections, to realize maximum savings by taking larger heats and making fuller use of the machine. By making a few changes to the equipment it would also be possible to accommodate 50-ton heats. Normal casting times of 1–1½ h can be considered as the practical maximum, and maximum tonnage cast within this allowable time should be the aim.

Therefore the following changes and additions to mould sizes were made. The 5½ in. × 21½ in. mould

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The author is Plant Superintendent of Atlas Steels Ltd., Welland, Ontario, Canada.

Table I
COMPARISON OF OPERATIONS
Ingot Casting *v.* Continuous Casting

Ingot Casting	Continuous Casting
1 Electric furnace	1 Electric furnace
2 Ladle	2 Ladle
3 Crane transport to pouring platform	3 Crane transport to tilting cradle
4 Ingot mould	4 'Concast' machine
5 Rail transport to stripper	5 Crane transport from machine
6 Stripper	6 Semi-finished product
7 Rail transport to soaking pits	
8 Crane transport to soaking pits	
9 Soaking pits	
10 Crane transport to blooming mill	
11 Blooming mill	
12 Semi-finished product	

was replaced by one measuring $6\frac{5}{8}$ in. × 24 in. This larger size has the advantages of providing more tonnage per unit of casting, heating, and rolling time, as well as providing heavier individual coils (and thus better yield) for the strip mill. In addition to this it allows more edge-working during rolling, thereby giving better surface and edge quality. This larger size will also facilitate the casting of 50-ton heats when the changes to the machine (now being engineered) are completed.

As operation of the new Sendzimir hot planetary strip-mill progressed, it was also decided to try to cast continuously a thinner slab section, which could be fed directly to this mill without any intermediate processing other than conditioning of the as-cast slabs, which could feed directly into both the planetary mill for strip, or be cut into shorter sections for direct use in the sheet mill. At present this is being done experimentally and while it is not the most economical size for strip, because of the lighter-weight coil, it has been possible to demonstrate that the necessary

Table II
COMPARISON OF 'CONCAST' AND INGOT PROCESSING TO STAINLESS SHEET

$5\frac{1}{2}$ in. × $21\frac{1}{2}$ in. Slab to Sheet	Ingot to Sheet
1 Cast and cut to 8 ft 6 in. lengths	1 Cast ingots
2 Transfer hot to soaking pits	2 Transfer hot to soaking pits
3 Cog to 14 in. × 3 in.	3 Cog to 14 in. × 3 in.
4 Yield tap wt. to rolled slab = 94%	4 Yield tap wt. to rolled slab = 81%
5 Grind all over	5 Grind all over
6 Cut to sheet bar lengths	6 Cut to sheet bar lengths
7 Yield tap wt. to sheet bar = 87·5%	7 Yield tap wt. to sheet bar = 75·6%
8 Process to sheet	8 Process to sheet
9 Yield tap wt. to sheet = 65%	9 Yield tap wt. to sheet = 56%
Overall yield pick-up = 9%	

Table III
COMPARISON OF 'CONCAST' AND INGOT PROCESSING TO STAINLESS STRIP

$5\frac{1}{2}$ in. × $21\frac{1}{2}$ in. Slab to Strip	Ingot to Strip
1 Cast and cut to 8 ft 6 in. lengths	1 Cast ingots
2 Grind all over	2 No grinding
3 Transfer to soaking pits	3 Transfer to soaking pits
4 No intermediate rolling or grinding	4 Roll to bloom and spot grind
5 Roll to $2\frac{1}{2}$ in. thick × 12–18 in. wide	5 Roll to $2\frac{1}{2}$ in. thick
6 Yield tap wt. to rolled slab = 92%	6 Yield tap wt. to rolled slab = 77%
7 Grind all over	7 Grind all over
8 Process to strip	8 Process to strip
9 Yield tap wt. to strip = 65%	9 Yield tap wt. to strip = 54%
Overall yield pick-up = 11%	

quality requirements can be met. This use of the machine is being fully explored.

The $5\frac{1}{2}$ in. × $7\frac{1}{2}$ in. mould was abandoned after an exhaustive programme, when it appeared that this near-square section presented considerable difficulty in obtaining good centre quality, would not accommodate 30-ton heats (or larger), and also gave poor tonnage performance on the blooming mill owing to its relatively small size. This section was replaced by a 7 in. × 15 in. mould which was designed as a universal size to be used for rolling all grades into large-diameter bars and small flat sections, and for forging application in machinery and tool steels.

A $6\frac{1}{4}$-in. square mould was also purchased to produce a cast section of SAE 1010–1045, which is extruded directly into seamless pipe with only spot surface conditioning of the as-cast billets. This programme is proving very worthwhile with some excellent quality and yield results; thus this section is now being double-stranded to accommodate 30-ton heats (and 50-ton heats in the near future). Squares of $6\frac{1}{4}$ in., of various grades, are also being cast for use directly in the company's bar mills and although this operation is still experimental, savings are realized.

Square sections of 7 in. and $8\frac{1}{2}$ in. are now being engineered for double stranding to provide larger as-cast sections to be extruded directly into larger-diameter seamless pipe.

Table IV
CURRENT MOULD SIZES AND PRODUCTION RATES, APRIL 1958

Mould Size	No. of Strands	Ladle Nozzle, in.	Tundish Nozzles		Casting Speed, in./min	Prod. Rate, tons/h
			No. per Tundish	Size, in.		
$4\frac{1}{2}$ in. sq.	1	1	1	$\frac{1}{2}$	60	8
$6\frac{1}{4}$ in. sq.	1	1	1	$\frac{5}{8}$	53	16
$6\frac{1}{4}$ in. sq.	2	1	2	$\frac{5}{8}$	53	32
$2\frac{1}{2}$ in. × 17 in.	1	1	3	$\frac{1}{2}$	80	25
7 in. + 15 in.	1	1	1	$\frac{7}{8}$	50	40
$6\frac{1}{8}$ in. + 24 in.	1	1	2	$\frac{3}{4}$–$\frac{7}{8}$	50	60

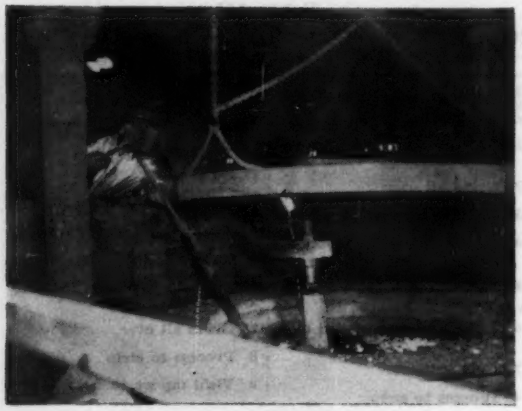


Fig. 1—Bottom-pouring ladle used in continuous casting

These square sections being produced directly for shipment as-cast and spot-conditioned to be extruded into seamless pipe are a good example of how profits can be realized on a plain carbon steel by the elimination of a rolling operation, and increased shipping yields.

A summary of the current mould sizes and their production rates is shown in Table IV.

INSTALLATION AND OPERATION

Several types of continuous-casting machines, differing mainly in mould design and mounting, exist at present. The installation at the author's company which was completed in December 1953, is of the Junghans–Rossi design employing a reciprocating mould. The first cast was made on 20th January, 1954. Since that time, numerous changes to operating and control equipment have been necessary. The most significant of these was in ladle practice, with lip-pour ladles being replaced by the conventional bottom-pour type. Although lip pouring lends itself readily to automatic control and regulation of metal flow, bottom pouring removes the need for special ladles, tilting mechanisms, and top heating of the ladle during casting, as well as delivering cleaner steel and providing adequate speed control. Figure 1 shows the type of ladle now in use.

Steel to be continuously cast has to date been produced in 6, 12, and 30-ton basic-arc furnaces. The heats are tapped into conventional refractory-lined ladles preheated to about 1400° F. The ladle is then transferred to the base of the casting machine by an electrically driven ladle-transfer car and hoisted by crane to the casting floor. The pouring process is shown in the schematic drawing (Fig. 2) of the side elevation.

When the ladle is properly positioned, the ladle nozzle is opened and the molten metal is directed into a tundish (Fig. 3), preheated to about 2500° F. The tundish is a two-compartment refractory-lined box (Fig. 4) designed to deliver a low-velocity, slag-free, precisely positioned stream of metal to the mould below. The rear compartment of the tundish receives the molten metal and a dam holds back any slag or foreign material that may enter. The front chamber

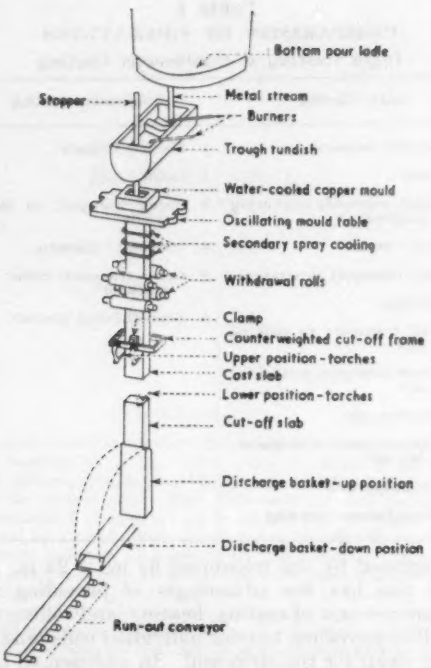


Fig. 2—Schematic drawing of side elevation of machine

contains the refractory nozzle through which the metal is directed into the mould. A uniform flow to the mould is maintained by keeping a constant head of metal in the tundish. This head will usually vary from 14 in. to 20 in., depending upon size being cast.

The mould is manufactured from a solid block of high conductivity, oxygen-free copper. Restrictor rods are inserted in a series of drilled water-cooling passages to promote turbulent, high-velocity flow and hence maximum heat transfer at the mould faces (Fig. 5).

In the preparations for casting, a dummy bar is inserted in the machine. It extends from the lower set of pinch rolls and up into the bottom of the mould. The top of the dummy bar, to which square-

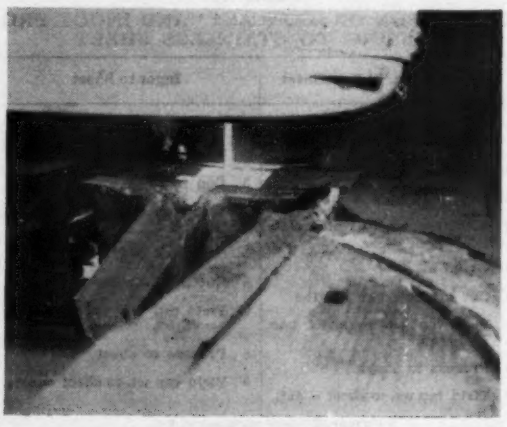


Fig. 3—Molten metal tapped into preheated tundish

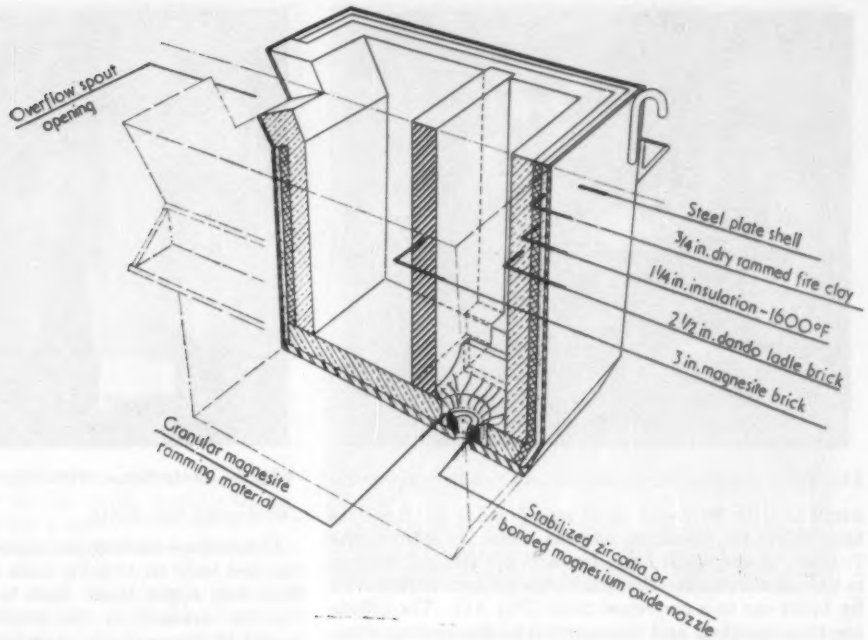

Overflow spout opening
Steel plate shell
3/4 in. dry rammed fire clay
1 1/4 in. insulation - 1600°F
2 1/2 in. dando ladle brick
3 in. magnesite brick
Granular magnesite ramming material
Stabilized zirconia or bonded magnesium oxide nozzle

Fig. 4—Cross-section through tundish

headed bolts are fitted, acts as a stool and anchorage for the solidifying metal when pouring starts. Asbestos rope is packed in the space between dummy bar and mould walls to prevent molten-metal leakage (Fig. 6).

The flow of the mould cooling water and the mould lubricant is started when the flow of metal into the mould begins. Rapeseed oil, used as the lubricant, is introduced about the top edges of the mould cavity and is allowed to run down the inner walls. It serves to wet the mould and minimize sticking. A propane-gas atmosphere to minimize oxidation is maintained around the molten stream leaving the tundish and over the metal in the mould.

When the metal fills the mould to a level of 3–4 in. from the top, the pinch-rolls and mould assembly are activated to extract the partially solidified cast section. The mould assembly permits a synchronized oscillation of about $\frac{3}{4}$ in., although it can be altered within the range $\frac{5}{8}$–$1\frac{1}{2}$ in. This is shown in Fig. 7.

The downward speed equals the extraction speed of the slab, while the return motion of the mould is three times its downward speed. The oscillation and pinch-roll speed is controlled by a variable-speed regulator (P.I.V.) which permits speed variations of 1–178 in./min. The machine speed is controlled by an operator in front of the mould. The ladleman stationed on an overhead platform controls the metal level in the tundish. These two operators must work as a closely co-ordinated team to maintain a uniform casting speed (Fig. 8).

The billet is withdrawn from the mould by the pinch-rolls and passes through a set of mould sprays, through the spray chamber, through the pinch-rolls, and into the cutting chamber. (Figure 9*a* shows a single strand and Fig. 9*b* a double strand at the pinch-rolls.) Here a hydraulically operated torch

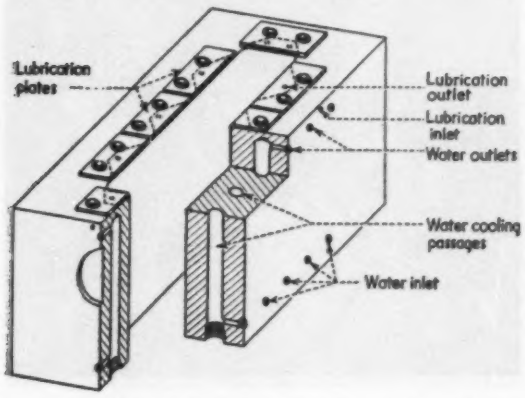
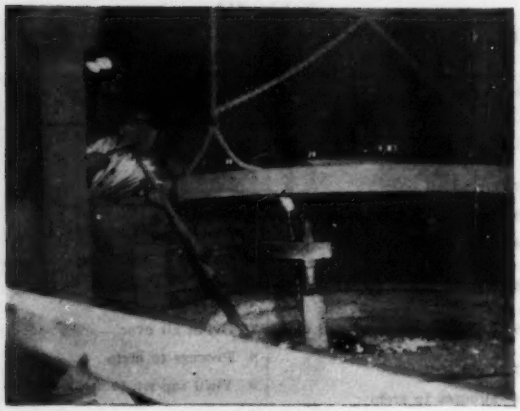


Fig. 5—Mould for continuous-casting machine

Fig. 6—Dummy bar and bolts



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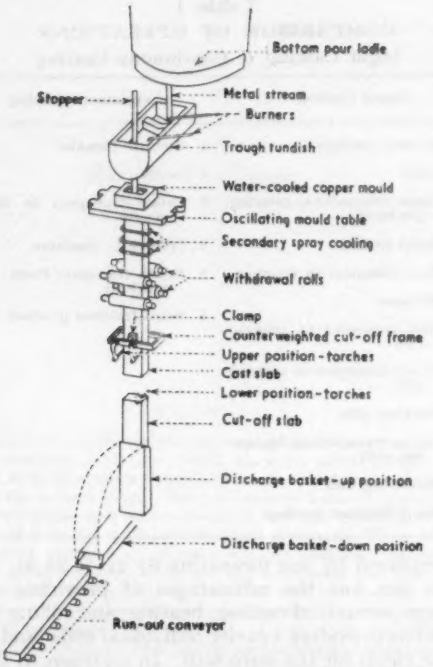

Fig. 2—Schematic drawing of side elevation of machine

contains the refractory nozzle through which the metal is directed into the mould. A uniform flow to the mould is maintained by keeping a constant head of metal in the tundish. This head will usually vary from 14 in. to 20 in., depending upon size being cast.

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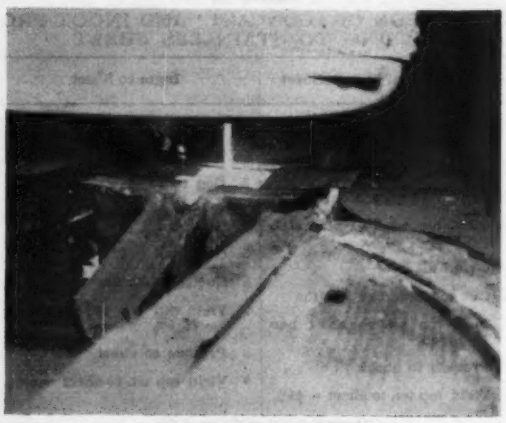

Fig. 3—Molten metal tapped into preheated tundish

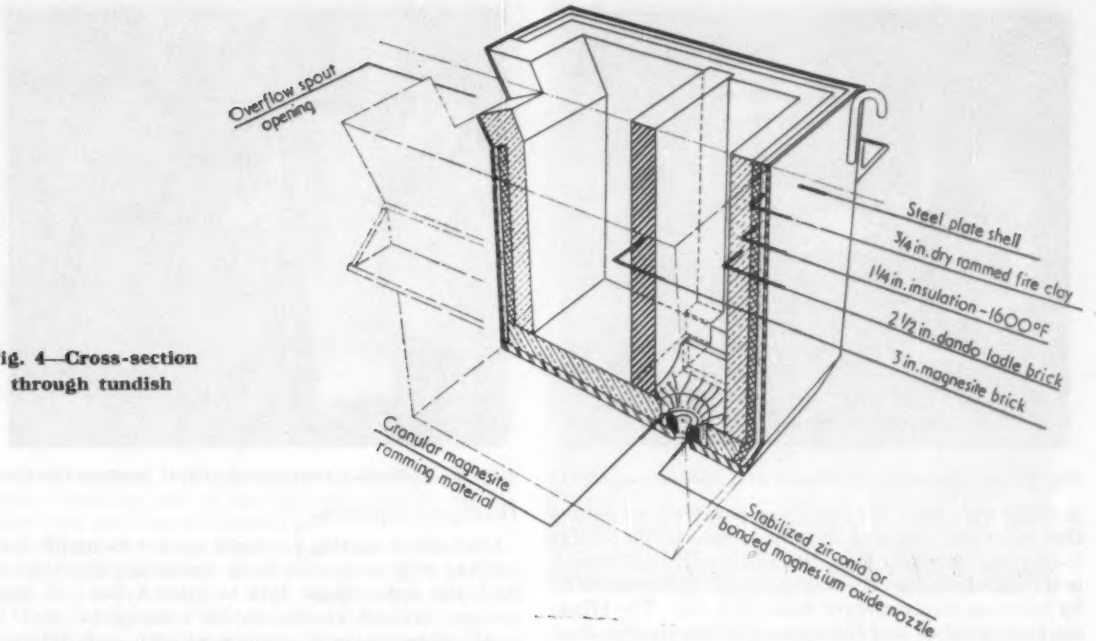
Overflow spout opening
Steel plate shell
¾ in. dry rammed fire clay
1¼ in. insulation – 1600°F
2½ in. dando ladle brick
3 in. magnesite brick
Granular magnesite ramming material
Stabilized zirconia or bonded magnesium oxide nozzle

Fig. 4—Cross-section through tundish

headed bolts are fitted, acts as a stool and anchorage for the solidifying metal when pouring starts. Asbestos rope is packed in the space between dummy bar and mould walls to prevent molten-metal leakage (Fig. 6).

The flow of the mould cooling water and the mould lubricant is started when the flow of metal into the mould begins. Rapeseed oil, used as the lubricant, is introduced about the top edges of the mould cavity and is allowed to run down the inner walls. It serves to wet the mould and minimize sticking. A propane-gas atmosphere to minimize oxidation is maintained around the molten stream leaving the tundish and over the metal in the mould.

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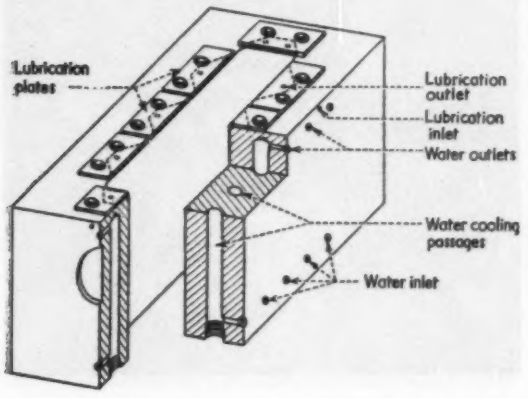


Fig. 5—Mould for continuous-casting machine

Fig. 6—Dummy bar and bolts

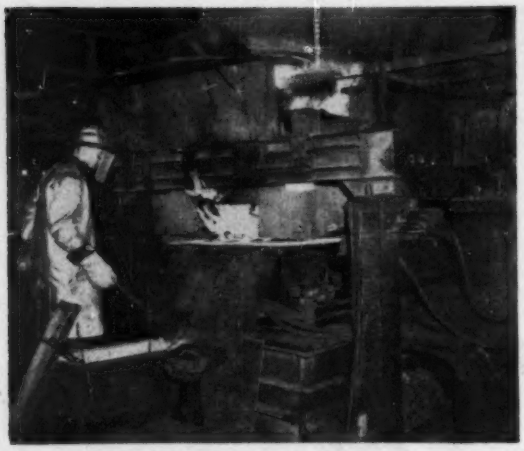


Fig. 7—Arrangement of mould and tundish assembly

Fig. 8—Ladleman controlling metal level in tundish

carriage with twin oxy-acetylene powder torches cuts the billet to required lengths between the limits 7–16 ft, as shown in Figs. 10*a* and *b*. The cut section is then lowered into the discharge pit and is removed by billet car to a conveyor table (Fig. 11). The billets are then weighed and transported to the cooling area, insulated boxes, or directly to the reheating furnaces for further processing (Fig. 12).

PROBLEMS OF DEVELOPMENT

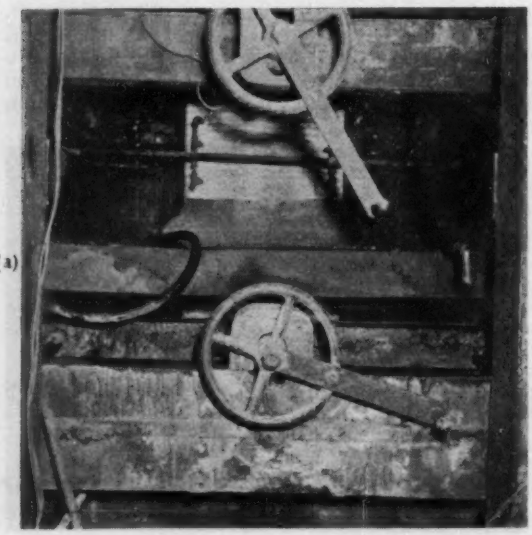
Fundamentally, higher temperature, lower thermal conductivity, and slower solidification rates make steel more difficult to cast continuously than the non-ferrous metals. Before a process to produce material of acceptable quality was developed, many unforeseen operational and technical problems had to be solved by means of considerable experimentation and study of very limited data. A résumé of these problems follows.

Developing Standards

Continuous-casting processes are not so simple that one has only to acquire facts concerning one type of steel and apply these data to other types. It soon became evident in the author's company that it would be necessary to experiment with each different type and the variations within that type. As a speciality steel producer, the company manufactures in the course of a year about 150–200 different chemical compositions, and thus it became very costly, difficult, and time-consuming to establish standards.

Temperatures

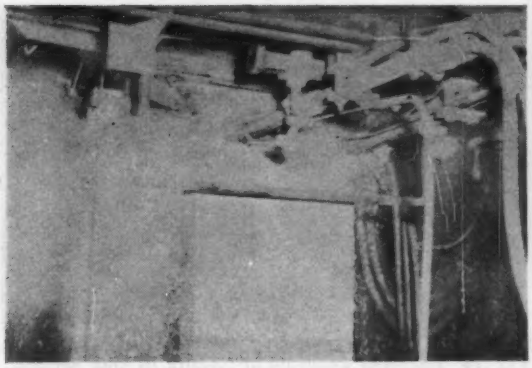
It was found that tapping temperatures at the furnace had to be very closely controlled to give the desired casting temperature $\pm$ 20° F at the machine. The importance of casting temperature becomes clearer when one considers the following:



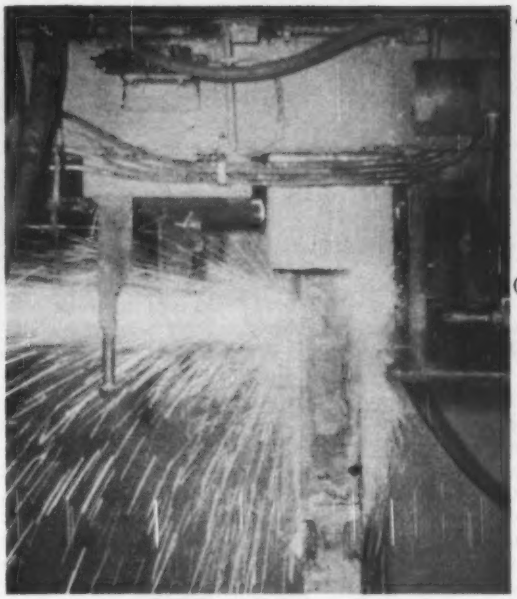
(a)

(b)

Fig. 9—(*a*) Single strand, (*b*) double strand at pinch-rolls



(a)



(b)

Fig. 10—Views of hydraulically operated torch carriage with twin oxy-acetylene powder torches cutting billets to required lengths

(i) Cold metal will inevitably result in a tundish nozzle freeze-up and/or trouble with skulling in the ladle, and can lead to dirty steel.

(ii) Hot metal may cause break-outs by the inner molten metal breaking through the partly solidified shell, and will develop a steep temperature gradient in the solidified rim. The thermal stresses set up by a steep temperature gradient during solidification have caused cracks in the casting.

(iii) In general, 100–140° F of superheat seems to be correct. The exact amount of superheat depends on the heat size, mould size, and grade of steel.

(iv) In larger cast sizes (over 4¼-in. square), the metal temperature at the mould level is independent of the temperature of the metal stream entering the mould and is, in fact, just a few degrees above the solidification temperature. The superheat of the liquid metal is lost below the mould in the spray chamber. This is shown by an increase in the B.t.u.'s removed by the water sprays as the pouring temperature is increased; i.e. the incoming metal washes on the solidified shell some distance below the mould.

Melting Techniques

The working of heats for continuous casting requires not only accurate temperature control but also oxidation and deoxidation practices that will ensure tapping of clean, fluid steel of low gas content. Stainless steels must not contain more than 6–8 p.p.m. of H_2, and low-alloy and plain-carbon steels not over 4–5 p.p.m. of H_2.

Aluminium contents in excess of 0·02% in plain-carbon and low-alloy steels, and 0·04% in stainless steels will lead to skulling of the tundish nozzle. An apparatus has been designed to feed aluminium wire into the mould at controllable rates, while vanadium has been used in some tool steels to replace aluminium for grain control.

Ladles

As mentioned previously, bottom pouring into the tundish is now standard practice. However, before the bottom-pouring trials, it was felt that lip or teapot pouring was necessary to provide a sufficiently controlled flow. Lip pouring and teapot pouring in itself required considerable development to provide metal

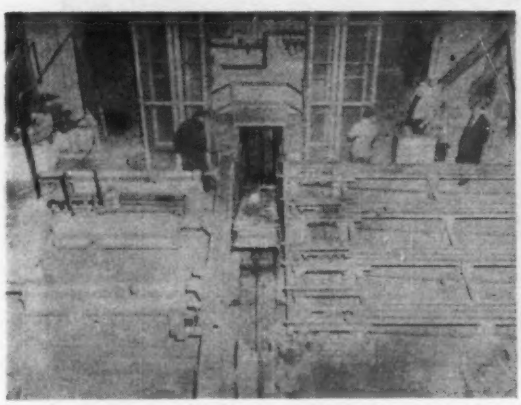


Fig. 11—Billet car removing billet to conveyor table

Fig. 12—Billet on conveyor table

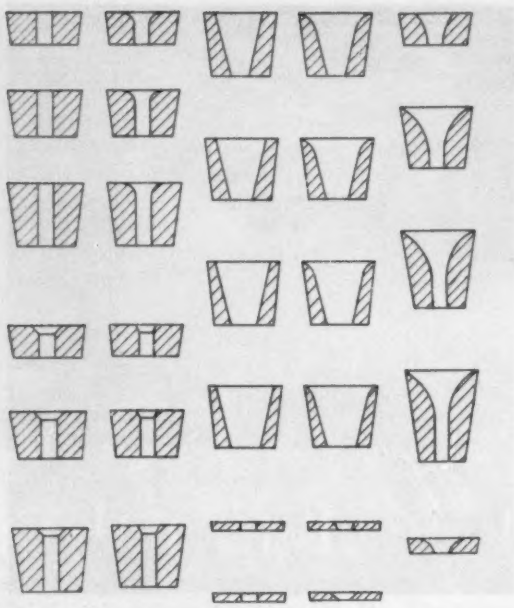


Fig. 13—Some tundish-nozzle designs tested

free of skulling, such as proper design of spouts and slag dams, protection of the metal in the spout, and careful selection of materials to be used in spouts and dams and the proper preheating of these materials. Had conventional bottom pouring been followed at the start, many problems and attendant difficulties would have been avoided.

Tundish and Tundish Nozzles

Initial tundish problems included determining the required metal head and volume, designing a suitable slag baffle, ensuring adequate insulation, and the production of a non-turbulent metal stream. The nozzles used were adopted only after extensive testing. Figure 13 shows some of the many designs tested.

Fig. 15—Extreme example of folding in slab section

Protective Atmospheres

It was found necessary to maintain a protective propane atmosphere around any exposed molten-metal streams and surfaces, to minimize oxidation and skulling and to prevent combustion of the mould lubricant.

Cooling and Casting Speeds

The casting speed must be as steady as possible, as variations in casting speed will cause:

(i) Changes in the thickness of shell formed in the mould, while pronounced changes in shell thickness will contribute to the occurrence of break-outs immediately below the mould

(ii) Local overcooling and undercooling can occur in the spray chamber. At high casting speeds, alternating local overcooling and undercooling will develop bridging and cause shrinkage cavities (Fig. 14).

Overcooling is also a source of internal and surface cracking. The surface condition of the cast bars depends largely on speed, and in general, increasing the casting speed improves the surface. For this reason, the $6\frac{5}{8}$ in. × 24 in. mould is poured with two

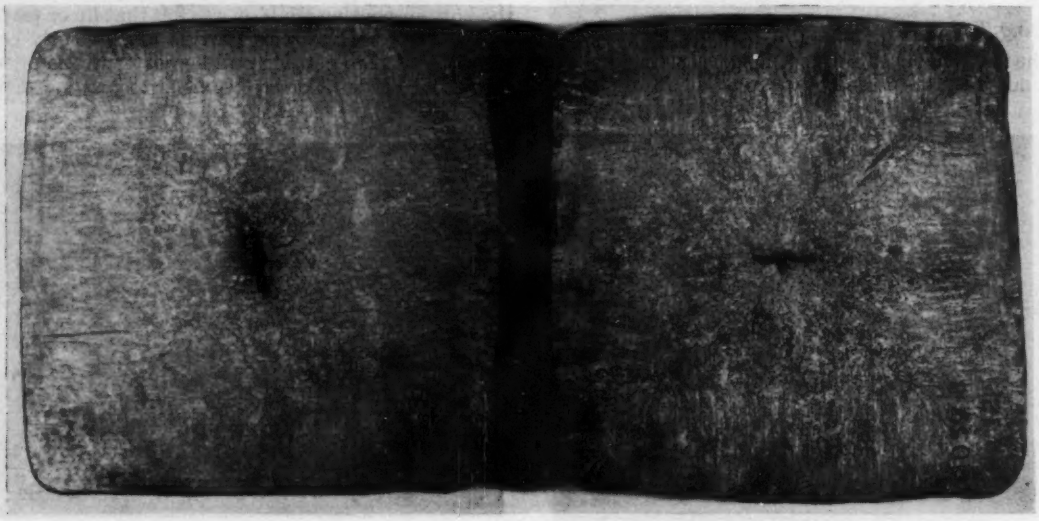


Fig. 14—Shrinkage cavities caused by local overcooling and undercooling

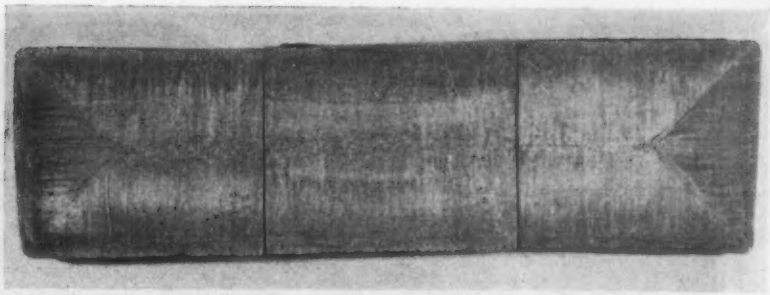


Fig. 16—Etch of as-cast 6⅝ in. × 24 in. 18–8 stainless-steel slab

nozzles in the tundish, which has increased the rate to 1 ton/min. Low casting speeds in slab sections can cause very serious surface defects to appear, such as 'folds.' Figure 15 shows an extreme example of folding.

These folds, although usually not nearly as severe as shown in Fig. 15, result from local overheating in the centre of the slab face while the area is still within the mould. Re-heating of this area causes the length of the surface to increase. Since the face is constrained longitudinally by the colder slab edges and by the mould wall, the increased length forces the hot and weak wall to buckle inwards, resulting in a fold. These folds sometimes crack open and bleed, and have been the cause of serious break-outs. Folds do not occur, however, if low casting speeds are avoided. For stainless steel 302 in a 6⅝ in. × 24 in. section, a casting speed of 35 in./min should be considered a minimum.

The use of 6⅝ in. × 24 in. slabs of 18–8 stainless is now well established at the author's company. Figure 16 shows an etch of as-cast 6⅝ in. × 24 in. stainless 18–8. One of the major problems met with was the formation of sub-surface pinholes in the slabs, and it was observed that casting speed influences the formation of pinholes. During several casts of 6⅝ in. × 24 in. stainless slabs, a portion was cast at reduced speed and pinholes were found in slabs cast at this lower speed. Although increasingly more is being learned about the conditions under which pinholes form (casting speed is important because of its influence on the solidification processes in the mould), the gas content (H_2 primarily) is still the most important factor, and an increase in this trouble can be expected during the warm, humid summer months.

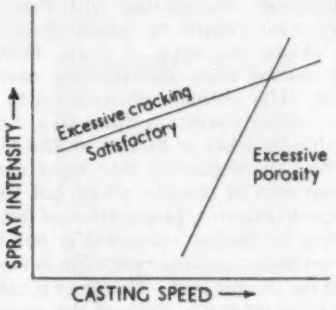


Fig. 17—Chart used to develop proper balance between cooling and casting speeds

The application of a de-gassing process to stainless steels before casting would undoubtedly provide an interesting solution to this problem.

Below the mould, the amount of spray water used and its distribution depend on the size of the bar, the rate of movement through the spray system, and the grade of steel being cast. To prevent excessive piping, the depth of liquid crater must be kept as short as is necessary to prevent short-term speed fluctuations from causing 'bridging' (squares and near-squares are the shapes most sensitive to the formation of pipe by bridging). To prevent cracking, the cooling stresses that are superimposed on the possible transformation stresses must be kept as low as possible.

Given a grade of steel, and a fixed mould size and spray system, it is possible to develop a graph (from examining etches produced under a variety of speeds and spray severity conditions) that outlines the main areas of excessive cracking, excessive porosity, and satisfactory quality. Such a diagram shows that, as the casting speed is increased, the control necessary to produce satisfactory bars becomes more difficult (Fig. 17). Some slight centre porosity is present in almost all grades cast except in slab form. Slight porosity is not serious in itself on sections which are to be further worked, as the working will usually weld up these minor discontinuities. Cracking, however, is the worst condition. In low-carbon steels, all but the heaviest gross cracks will weld up, although an end discard must be taken on such bars because of oxidation occurring along the crack during heating.

There is also a condition that 'appears' as cracks on deep-etched transverse samples cut from bars of as-cast low-alloy machinery steels. It is the result of segregation that occurs during the solidification process. It is thought that during the freezing of the steel, small cracks develop as the result of thermal stresses in the solidified shell, and liquid from the liquid/solid interface seeps back in along the crack. As it is of a different composition, it is impossible to see these lines in the rolled bar, but they are visible on both the deep etches and on metallographic specimens. It should be noted, however, that an investigation is being made to determine the composition of the segregate. Such defects persist from the 7 in. × 15 in. casting to the smaller (say 1 in. round) sizes rolled (Fig. 18). A preliminary study of their effects on mechanical properties has shown no cause to expect a significant difference from the properties of normal material. They are not apparent on fractured specimens, and are seen only on deep-

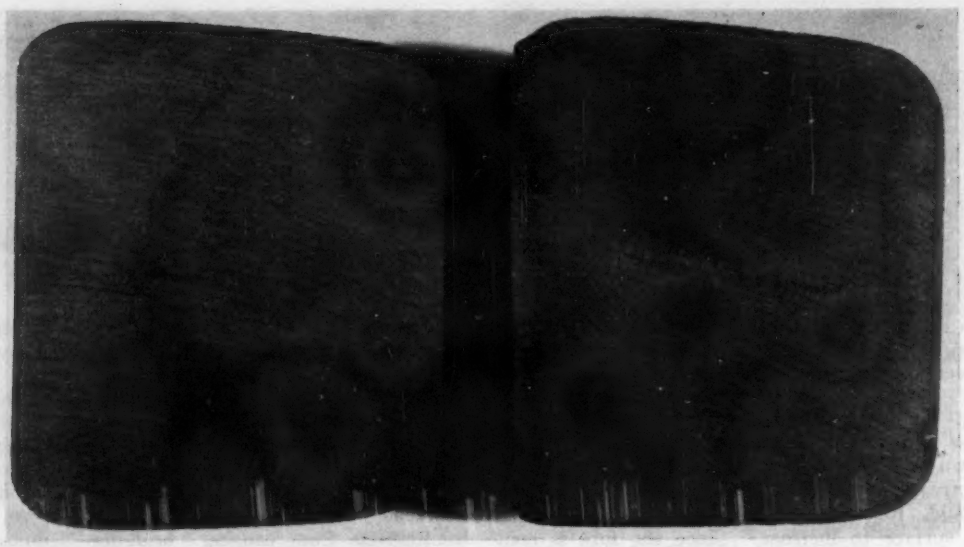


Fig. 18—Example of segregation occurring during solidification, small rolled bar

etched samples or polished and etched metallographic samples (Fig. 19).

The source of the thermal stresses believed to cause ' hot tears ' to develop is thought to be the development of a steep temperature gradient in the solidified shell. It is felt that this steep temperature gradient is caused by a combination of two factors, namely (*a*) excessive spray cooling, and (*b*) re-heating of the solid at the point where the incoming hot-metal stream first washes against the shell of the casting. This point is thought to be a considerable distance below the mould. The location of the segregate lines is found to be approximately between the centre and mid-radius of the section.

An investigation has been started to test the validity of the above explanation, for it is difficult to envisage that such segregation could develop naturally during the solidification of the bar. It is well established that ' coring ' occurs during the growth of dendrites, but these segregates are discrete, well defined inter-dendritic lines that are not associated with the growth of each dendrite. A promising attack on this problem has been to increase the spray severity directly below the mould but above the penetration depth of the incoming stream. A substantial decrease in the occurrence of ' line segregates ' has been noted.

ECONOMICS

The economic potential of continuous casting over conventional ingot casting is considerable once the initial development stage is completed and the regular production of a material of commercial quality has been reached. However, when this goal has been reached on some grades and sizes, it becomes necessary to carry on development of other grades and sizes to exploit fully the economic advantages of the machine. These two programmes (production and development) are in fact carried on simultaneously.

To offset the development cost and also make the machine ' stand on its own feet,' the author's company has a programme whereby a percentage of financial savings on production casting is diverted to offset development costs. Savings derived from continuous-casting operations can be outlined under casting costs and casting margin.

Casting Costs

These costs depend largely on the machine output during a specific period. An operation producing only 500 tons or less per month will give an operating cost of about double that for an operation producing 2500 tons or more in the same period. This rise in cost is due largely to the increased percentage of machine set-up time involved, lack of full utilization of labour, somewhat similar maintenance costs, and scheduling problems. When the machine is operating at a low level (say one-shift operation, i.e. 8 h per 24 h), it becomes difficult to schedule heats to fit this time without incurring overtime charges in the casting house and/or long heat times in the melt shop caused by delaying the tap.

Since the rate of production with a single machine installation is more dependent on scheduling of heats from the melting department than on the actual casting operation, the casting cost does not vary particularly with regard to grade or section cast. Figure 20 shows the type of curve developed by correlating casting costs and tonnage cast within a fixed period. The ultimate objective is to bring the cost of the casting operation down to a figure which is comparable to what is known as the pouring pit cost, i.e. the cost of pouring into ingot moulds with its attendant cost of moulds, plugs, hot tops, mould coating, pipe eliminator, preparation of hot tops, etc.

If a rolling or forging operation is not by-passed, then the continuous-casting operation is merely being substituted for the pit cost. Therefore if casting costs are higher than pit costs, some of the savings gained through improved yield are nullified. This is particularly important in the casting of low-priced steels

such as low alloy and plain carbon where cash return from improved yields is considerably less than on the high-alloy types. On some of the lower priced steels where the section cast does not permit elimination of a rolling or forging operation, the casting of these steels does not become economical until casting cost is reduced to a level equal to or below pit cost.

It was previously stated that the rate of production for an individual casting machine depends mainly on scheduling of heats from the melt shop. The frequency with which mould sizes have to be changed affects to some extent the production rate and consequently the cost per ton. For this reason, the developmental or experimental portion of the casting programme must be scheduled to disrupt as little as possible the programme of casting commercial heats.

Casting Margin

The casting margin is the amount a manufacturer

Fig. 19—Example of segregation in deep-etched and polished and etched metallographic samples

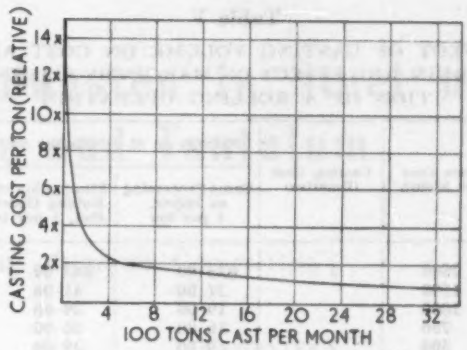


Fig. 20—Effect of volume on casting costs

can afford to pay for the casting operation (plus its attendant services such as maintenance and metallurgical), royalties, and scrap losses without exceeding the cost of a similar end product as produced from ingots. As is shown in Fig. 21 this margin depends mainly on:

(i) Casting cost
(ii) Metal value per ton
(iii) Percentage improvement in yield
(iv) Elimination of processing steps.

Referring to Fig. 21, the casting operation giving the margin as shown in line 'A' has not allowed the by-passing of a rolling or forging operation and hence on the very low-alloy and plain-carbon steels a loss will be shown unless steps are taken to move the margin line to a higher level (as shown by line 'B') by any of the following steps:

(i) By-passing a rolling or forging operation
(ii) Lowering the total casting cost
(iii) Increasing yields (shown in line 'C').

The savings or casting margin in line 'A', where a forming operation is not eliminated, would appear to be the sum of the following:

(1) Savings in non-recoverable metal losses due to melting oxidation, as it is not necessary to melt as much steel to provide the required finished product.
(2) Savings in melting labour and overhead charges because of the smaller number of heats required to fill a specific order.
(3) Savings from lower scale and scrap losses in the rolling operation, i.e. the smaller quantity of material

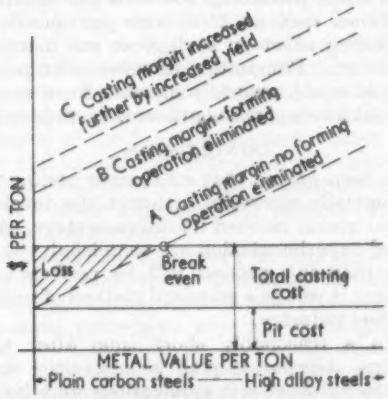


Fig. 21—Factors affecting casting margin

Table V

EFFECT OF CASTING VOLUME ON COST AND MARGIN, AND EFFECT ON MARGIN BY ELIMINATION OF A ROLLING OPERATION

Tons Cast per Month	Casting Cost (Relative)	Savings on 18–8 Stainless Steel	
		Same Processing as Ingots, $ per ton	Elimination of a Rolling Operation, $ per ton
2500	1 ×	$23·00	$43·00
1500		21·00	41·00
1000		19·00	39·00
750		16·00	36·00
500	2 ×	9·00	29·00
250	3 ×	(17·00) loss	3·00
100	6 ×	(59·00) loss	(39·00) loss

rolled requires less heating time and provides higher yields than a similar ingot product.
(4) A small savings in rolling cost because the smaller continuously cast section requires fewer mill passes.
(5) Savings in elimination of most of the pouring-pit and all of the hot-top costs.

The elimination of a processing operation (rolling or forging) will usually move the margin immediately to a level where a profit is shown even on plain-carbon steels. However, if it is not possible to eliminate a processing operation then casting cost must be reduced, and since the factor most affecting casting cost is total tonnage cast within any specific period, it becomes necessary to provide this increased tonnage to the machine.

Because of this effect of volume on casting cost, if sufficient tonnage of high-alloy grades is not available then the required volume should be obtained on the low-alloy and plain-carbon steels. The reduction in casting cost thus obtained, even if insufficient to show a profit on the low-alloy tonnage, can provide a sufficient increase in margin on the higher-alloy grades to increase overall profit.

Table V shows the effect of volume (tons per month) on casting cost and savings for 18–8 stainless steel. If 2500 tons per month are taken as a unit base of casting cost, then casting only 500 tons per month doubles this cost, 250 tons per month triples it, and the cost when producing 100 tons per month soars to six times that at 2500 tons per month. The corresponding effect on savings at one margin level is also shown. Elimination of subsequent processing operations would naturally increase these savings at the various levels of the continuous-casting operation.

CONCLUSION

It has been proved that continuous casting of steel is commercially successful, although the development has by no means reached its ultimate stage. As more work and experimentation are completed, the author believes that this process will be perfected to the degree that it will be a standard method of production in the steel industry.

Within a reasonably short time after start of operations, acceptable-quality austenitic stainless-steel slabs for sheet-mill applications were being cast in the author's company. As a result of further development and experimentation, the continuous-casting machine described in this paper is considered a production unit for the following items:

(i) Austenitic stainless-steel slabs, 6¾ in. × 24 in. for both sheet and strip applications
(ii) Austenitic stainless-steel billets, 6¼ in. square, and 7 in. × 15 in. for bar and wire applications
(iii) Selected tool-steel and machinery-grade billets 4¼ in. and 6¼ in. square, and 7 in. × 15 in., for further reduction to smaller billets and subsequent application on bar and wire
(iv) Seamless pipe billets for extrusion as-cast, 6¼ in. square.

Because it is believed that the largest savings can be achieved in the following ways, these are now being investigated by the author's company:

(i) Elimination of processing operations
(ii) Casting of higher-alloyed steels which provide greater yield savings
(iii) Reduction of casting cost by increasing volume cast.

Item (i) is being investigated by casting sections which can by-pass blooming and forging operations and go directly to finishing mills or be shipped in the as-cast condition. Examples of this are (*a*) the casting of 2¼ in. × 17 in. slabs which can go directly to the hot mills in the sheet and strip departments; (*b*) the casting of 4¼ in. and 6¼ in. square billets to go directly to the bar finishing mills; (*c*) the casting of 4¼ in., 6¼ in., 7 in., and 8½ in. square sections to be extruded directly into seamless pipe or be forged directly into finished products such as crankshafts.

Item (ii) is being pursued constantly as part of the development programme, and includes recent successful castings of slab sections of stainless 331 (15% Cr–35%Ni) and 'Permalloy 78' (78%Ni) grades. Experimental castings of various grades of high-speed steel in 4¼ in. and 6¼ in. square sections are also being carried out with a fair measure of success.

The volume required in item (iii) to help lower the casting cost is being supplied as much as possible by the production items of high-alloy grades such as the slab sections for stainless sheet and strip. However, this volume is being augmented by large tonnage orders of the low-alloy grades in sections which can be cast to give satisfactory quality on a production basis. The volume required on these low-alloy and plain-carbon steels can be handled most economically by using the largest melting furnace available (50 tons' capacity) and by multiple stranding; therefore the machine is now being engineered to accommodate 50-ton heats to be double-stranded in sizes up to 8½ in. square.

In conclusion it should be said that it is not merely sufficient that the end product derived from continuous casting may be cheaper than a similar product derived from ingots. The savings attained must be sufficiently great to give a reasonable return on the substantial capital investment involved even though this investment may be less than that required for conventional ingot processing.

Acknowledgments

The author expresses his sincere appreciation to all those who so kindly assisted in the preparation of this paper.

The Determination of Tungsten in Steel not containing Niobium and Tantalum

By the B.I.S.R.A. Methods of Analysis Committee

SYNOPSIS

A gravimetric procedure has been developed for the determination of tungsten in steel in the range 3–32% tungsten. Particular attention has been paid to the analysis of high-speed steels containing molybdenum. A method is recommended in which tungsten is determined as tungstic oxide after separation by oxidation and hydrolysis, using cinchonine as an aid to precipitation. 1593

INTRODUCTION

EXPERIENCE with the British Standard method, B.S.1121: Part 3: 1948, based on the reduction of iron to the ferrous state and hydrolysis precipitation of tungstic acid with the help of rhodamine B, has shown that it is liable to give high results on molybdenum steels owing to co-precipitation of molybdic oxide with the tungsten hydrolysis product.

The procedure has therefore been referred to the Methods of Analysis Committee for re-examination, and the experimental work which forms the basis of the present paper was undertaken by the Highly Alloyed Steels and Ferro-alloys Analysis Sub-committee.*

Although the method was not issued as a British Standard until 1948, it was developed during the early war years when it was necessary to find a substitute for cinchonine. Tungsten high-speed steels, including the high-molybdenum type, were not examined during the development of the method, as the use of cinchonine was not considered necessary for the complete precipitation of the large amounts of tungsten present in such steels.

The range of materials examined has been restricted to steels not containing niobium and tantalum.

DETAILS OF INVESTIGATION

The results in Table I show the degree of contamination from molybdenum obtained in tests on a high-molybdenum type high-speed tungsten steel when using the method of B.S.1121: Part 3: 1948. These results show that the perchloric acid treatment is not effective in extracting co-precipitated molybdenum from the hydrolysis residue. The amount which remains, varying from 12·6 to 15·4 mg of molybdic oxide, would account for a positive error of 0·50–0·61% in determinations of tungsten calculated on a 2-g sample-weight basis.

The degree of molybdenum contamination which occurs during the hydrolytic precipitation of tungstic acid is known to be influenced by a variety of factors such as the concentration of tungsten and molybdenum present in the solution, the ratio of their concentrations, the acidity of the solution, and the use, or otherwise, of organic reagents as auxiliary precipitants. Conditions which favour a maximum yield of tungstic acid also favour an increase of molybdenum contamination and these conditions exist in B.S.1121: Part 3: 1948 where use is made of both sulphurous acid and rhodamine B to promote complete precipitation of tungsten. The hydrolysis residue is therefore likely to be contaminated with molybdenum in unfavourable cases, e.g. when molybdenum is present in substantial quantity and particularly when large amounts of tungsten and molybdenum are present together.

The important point to note is not so much that molybdenum is co-precipitated, as this can be expected, but that it is not effectively extracted by the perchloric acid treatment of the hydrolysis residue and that the method makes no other provision for the removal or determination of residual molybdenum.

In considering various suggestions for the reconstruction of the method, it was obviously necessary to replace the perchloric acid treatment by some other means of residue purification, e.g. by fusion of the ignited oxides with sodium carbonate, followed by solution of the fusion products in water, removal of iron and titanium by filtration, and correction for chromium, molybdenum, and vanadium impurities based on colour tests for each element on suitable aliquots of the filtrate.

Some attention was given to the possibility of developing an improved procedure for the initial separation of the tungstic acid from the steel solution, as the usual procedures were known to give incom-

* The constitution of the Highly Alloyed Steels and Ferro-alloys Analysis Sub-committee at 31st March, 1958, was: Mr. B. Bagshawe (*Chairman*), Brown-Firth Research Laboratories; Mr. C. D. Atkinson, Sheffield Testing Works Ltd.; Mr. L. E. Gardner, Edgar Allen and Co., Ltd.; Mr. S. Harrison, Kayser Ellison and Co., Ltd.; Mr. J. D. Hill, Bragg Laboratory, N.O.I.D.; Mr. G. M. Holmes, London and Scandinavian Metallurgical Co., Ltd.; Mr. L. Kidman, English Steel Corporation Ltd.; Mr. G. Murray, Brown Bayley Steels Ltd.; Mr. R. T. Postlethwaite, Samuel Fox and Co., Ltd.; Mr. L. N. Taylor, Samuel Osborn and Co., Ltd.; Mr. J. L. West, Hadfields Ltd.; Mr. W. Wright, Permanent Magnet Association. Mr. J. W. Flint, Wm. Jessop and Sons Ltd. (retired 1957) and Mr. C. L. Grayson, English Steel Corporation (retired 1955, now with Edgar Allen and Co., Ltd.) also took part in the investigation.

Paper MG/DC/19/58 of the Metallurgy (General) Divisional Panel of the British Iron and Steel Research Association, received 17th June, 1958.

Table I

MOLYBDENUM CONTAMINATION OF TUNGSTIC OXIDE RESIDUES

British Standard Method 1121: Part 3: 1948
Steel BCS 220 (6·7% W, 4·17% Mo)

	MoO_3 in residue, mg	Mo equiv., mg
Hydrolysis residue	21·9	14·6
	22·2	14·8
Residue after perchloric acid treatment	24·4	16·3
	15·4	10·3
	13·3	8·9
	12·6	8·4

plete recovery on low-tungsten steels, e.g. the B.S. method is limited to steels containing more than 0·5% tungsten.

Table II shows the results obtained by one member of the Sub-committee in a comparison of various hydrolysis procedures. These included the use of hydrochloric acid alone and with cinchonine or rhodamine B, and sulphurous acid alone and with rhodamine B. In each case the efficiency of the separation has been assessed by determination of the tungsten remaining in the filtrate by means of the colour reaction with toluene 3:4 dithiol.

It will be seen that the best recoveries are obtained with sulphurous acid hydrolysis and rhodamine B as auxiliary precipitant, the particular combination used in the B.S. method. Although the best of the procedures tested, the recovery is not entirely satisfactory. It was considered that as sulphurous acid hydrolysis (ferrous solution) was obviously superior to hydrochloric acid hydrolysis (ferric solution), a combination of cinchonine with sulphurous acid might, at least, be as effective as the sulphurous-acid–rhodamine B combination.

Several other organic precipitation agents were considered or tried, including Yoe's reagent (*anti*-1: 5-di (*p*-methoxyphenyl)-5-hydroxamino-3-oximino-1-pentene), and various benzidene derivatives, e.g. *pp'* diaminostilbene developed by Belcher* and his co-workers.

* R. Belcher and A. J. Nutten: *J. Chem. Soc.*, 1951, p. 1516.

Table II

SEPARATION OF TUNGSTIC ACID FROM STEEL SOLUTIONS: COMPARISON OF HYDROLYSIS CONDITIONS

	Tungsten present, %	Tungsten found, %	Tungsten in filtrate (Dithiol), %
A Hydrolysis from 15% HCl sol.	0·78	0·72	0·07
	0·21	0·12	0·105
B As A + Cinchonine	0·78	0·70	0·07
	0·21	0·11	0·115
C As A + Rhodamine B	0·78	0·66	0·12
	0·21	0·13	0·09
D Sulphurous Acid Hydrolysis	0·78	0·67	0·12
	0·21	0·09	0·15
E Sulphurous Acid Hydrolysis + Rhodamine B	0·78	0·74	0·04
	0·21	0·20	0·05

Table III

DETERMINATION OF TUNGSTEN IN THREE STEELS USING PRELIMINARY FORM OF RECOMMENDED METHOD

Analyst	Tungsten, %		
	MGS 50 | High-speed BCS 220 /	MGS 128 2% Cr Steel	MGS 243 | 19% Cr BCS 235 / 9% Ni
1	6·78	2·16	0·63
2	6·67	2·19	0·63
3	...	2·13	0·65
4	6·77	2·19	0·67
5	6·67	2·15	0·60
6	...	2·24	0·65
7	6·82	2·20	0·59
8	6·67	2·17	0·63
9	6·77	2·20	0·64
10	6·72	2·18	0·61

Tests with Yoe's reagent showed that it was about equal to cinchonine as a precipitant for tungstic acid, but its use led to increased contamination from molybdenum. For example, 2 and 3 mg of molybdic oxide were found in the tungstic oxide residues from two tests on a steel containing only 0·26% molybdenum, and 23·7 mg of molybdic oxide were found in the tungstic oxide residue from a test on the British Chemical Standard steel 220 containing 6·74% tungsten and 4·17% molybdenum.

The benzidine derivatives were unsatisfactory when applied to steel solutions either because of oxidation and destruction of the reagent by ferric iron or of incomplete recovery of tungsten when the precipitation was carried out at an acidity high enough to prevent co-precipitation of molybdenum.

Benzoin α-oxime was found to give a good precipitation of tungsten from solutions containing 20% or more of free hydrochloric acid. Precipitation from dilute sulphuric acid is less satisfactory and only approaches 100% in the range 10–15% sulphuric acid. Graphs showing the comparative efficiency of recovery are given in Figs. 1*a* and *b*. Since,

Table IV

DETERMINATION OF TUNGSTEN IN A SERIES OF ALLOY-STEEL SAMPLES USING RECOMMENDED METHOD

Analyst	Tungsten, %						
	MGS 292	MGS 50	MGS 166	MGS 286	MGS 186	MGS 48	MGS 306
1	2·95	6·62	10·08	12·34	18·30	20·99	31·83
2	2·90	6·74	10·14	12·48	18·34	21·06	31·50
3	2·93	6·61	10·02	12·44	18·31	21·01	31·53
4	2·92	6·66	10·03	12·39	18·36	20·98	31·62
5	2·96	6·62	10·16	12·49	18·40	21·24	31·69
6	2·94						31·70
7		6·76	10·04	12·41	18·26	20·95	31·54
8	2·93	6·77	10·17	12·58	18·40	21·23	31·63
9	2·93	6·60	10·09	12·42	18·36	21·05	
10	2·94	6·73	10·20	12·55	18·37	21·23	31·78
11	2·95	6·72	10·10	12·45	18·39	21·16	31·64
12	2·92	6·64	10·11	12·54	18·32	21·02	31·62
13	2·97						
Average	2·94	6·68	10·10	12·46	18·35	21·08	31·64
Range	2·90–2·97	6·60–6·77	10·02–10·20	12·34–12·58	18·26–18·40	20·95–21·24	31·50–31·83

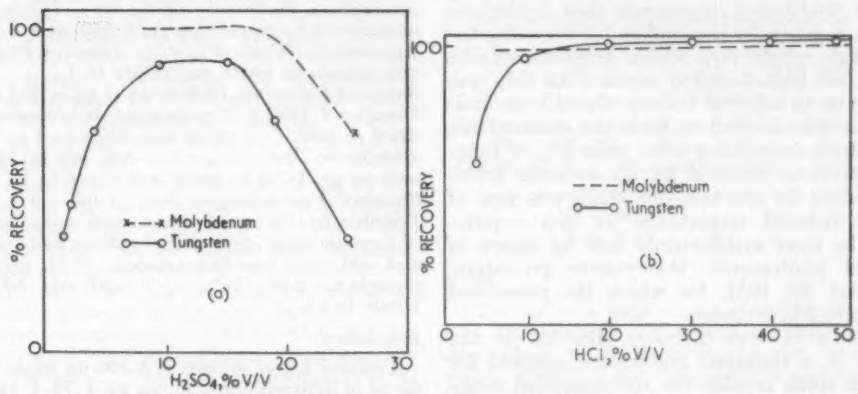


Fig. 1—Precipitation of 2·5 mg tungsten and 5·0 mg molybdenum with benzoin α-oxime from 5 g iron (*a*) in varying sulphuric acid concentrations, (*b*) in varying hydrochloric acid concentrations

however, precipitation of molybdenum is also more or less quantitative, the potential value of precipitation with benzoin α-oxime depends on whether some convenient and effective means is available for separating the two elements after precipitation. Determination of the molybdenum in the residue by means of a specific colour reaction is only likely to be of sufficient accuracy when the amount of molybdenum is small and the tungsten/molybdenum ratio in the steel is comparatively high, e.g. 10:1 or more.

A method in which molybdenum was precipitated as sulphide from a tartaric solution of the mixed oxides proved unsuccessful owing to incomplete recovery of tungsten from the filtrate. As no other ready means of separating the two elements was available no further work with methods which involved extensive co-precipitation of molybdenum, e.g. benzoin α-oxime, tannin, etc., was undertaken.

When these investigations were complete, cinchonine was again commercially available and in view of previous indications of its suitability, a tentative procedure was drafted based on sulphurous acid hydrolysis with cinchonine as auxiliary precipitant.

The tungsten was determined by the loss in weight resulting from fusion of the residue with sodium carbonate and correction was made for co-precipitated chromium and molybdenum by colour tests on aliquots from the fusion extracts. The results obtained on three steels are shown in Table III. The results were considered promising on the high molybdenum–tungsten standard steel, but those on the two low-tungsten steels were somewhat erratic.

Two or three members of the Sub-committee determined the unrecovered tungsten in the hydrolysis filtrates by photometric methods using the dithiol or thiocyanate colour reactions and the average amounts found were 0·04% for MGS 50 (6·7% tungsten), 0·05% for MGS 128 (2·2% tungsten), and 0·05% for MGS 243 (0·68% tungsten). It will thus be seen that the recovery is proportionately inferior for the two lower-tungsten steels. This is

Table V

APPROXIMATE COMPOSITION OF SAMPLES MGS 48, 50, 128, 166, 186, 243, 286, 292, AND 306

Sample No. MGS	Composition, %									Remarks
	C	Mn	Si	Ni	Cr	V	Mo	Cu	Others	
48	1·0				4·5	1·5	0·6		Sn 0·04 Co 12	High-speed steel
50	0·9	0·3	0·30	0·2	4·6	1·4	4·2	0·14	Sn 0·04 Co 0·67	BCS 220 High-speed steel
128	0·5	0·3			1·8	0·18			As 0·04	2% chromium steel
166					4·0	4·0		0·18		High-speed steel
186				0·03	3·9	1·2				18–4–1 High-speed steel
243	0·14	0·46	0·8	8·73	19·0	0·02	0·04	0·98	Ti 0·62	Stainless steel
286	1·2	0·3	0·3		4·5	4·0				13–14% tungsten steel
292									Fe 96·9	3% tungsten steel
306									Fe 68·0	32% tungsten melting base

in line with traditional experience that hydrolysis precipitation is generally incomplete for low-tungsten steels, although satisfactory within acceptable limits of accuracy for high-tungsten steels. As this was considered to be an inherent feature of acid hydrolysis procedures, it was decided to limit the scope of the method to steels containing more than 3% of tungsten. The previous demand for an accurate gravimetric procedure for low-tungsten steels was now of considerably reduced importance as this requirement could be more satisfactorily met by means of the standard photometric thiocyanate procedure, B.S.1121: Part 32: 1954, for which the prescribed range was up to 3% tungsten.

Subsequent work was therefore directed to the development of a standard gravimetric method for high-tungsten steels outside the recommended range of the photometric method with the object of the two methods becoming complementary in providing for the complete range of tungsten contents found in steel.

The method using sulphurous acid hydrolysis and cinchonine was, therefore, re-drafted with minor modifications and subjected to examination on a representative selection of highly alloyed steels covering a range of tungsten contents of 3–32%. The results obtained are given in Table IV. The composition of the samples used in the examination is shown in Table V.

For tungsten contents of 3–32% it was found possible to draft an approved procedure which is given in its final form in the Appendix.

CONCLUSION

The method developed as a result of this investigation has been found satisfactory for the determination of tungsten in a wide range of steels. The method is satisfactory for all tungsten contents above about 3%, but it is not directly applicable to steels containing niobium or tantalum.

The method has been submitted to the British Standards Institution with a view to its acceptance as an approved British Standard superseding the earlier specification B.S.1121: Part 3: 1948.

APPENDIX

Revised Recommended Gravimetric Method for the Determination of Tungsten in Steel, Niobium and Tantalum absent

Range—For steels containing more than 3·0% of tungsten.

Reagents Required

Distilled water shall be used throughout the procedure and all reagents shall be of the highest purity obtainable.

Solutions

Sulphurous Acid (saturated)—Pass sulphur dioxide gas into water until a saturated solution is obtained.

Cinchonine Reagent (10% w/v)—Dissolve 50 g cinchonine hydrochloride in 500 ml of hydrochloric acid (50%).

Cinchonine Wash Solution (2% w/v)—Add 20 ml cinchonine reagent solution (10%) and 20 ml of hydrochloric acid (sp.gr. 1·16–1·18) to water and adjust to 1 l.

Ammonium Hydroxide (50% v/v)—Dilute 500 ml of ammonium hydroxide (sp.gr. 0·880) to 1 l.

Ammonium Nitrate (2% w/v)—Dissolve 20 g of ammonium nitrate in water and dilute to 1 l.

Standard Potassium Dichromate (1 ml = 0·1 mg Cr_2O_3)—Dissolve 0·1935 g of potassium dichromate (previously dried at 150° C) in water and dilute to 1 l.

Phosphoric Acid (50% v/v)—Add 500 ml of phosphoric acid (sp.gr. 1·75) to water and dilute to 1 l.

Standard Vanadotungstic Acid (1 ml = 0·1 mg V_2O_5)—Dissolve 0·1286 g of ammonium metavanadate, 4 g of tungstic oxide, and 10 g of sodium hydroxide in water and boil until free of ammonia. Cool, neutralize with phosphoric acid (50% v/v), and add 50 ml excess. Dilute to 1 l.

Procedure

Transfer 2 g of sample to a 600-ml squat beaker, add 60 ml of hydrochloric acid (sp. gr. 1·16–1·18) and digest until dissolved. Evaporate to dryness and bake lightly for 5 min. Cool, add 60 ml of hydrochloric acid (sp.gr. 1·16–1·18), heat until salts are dissolved and oxidize with nitric acid (sp.gr. 1·42) using only a slight excess. Evaporate to low volume (about 15 ml), add 30 ml of hydrochloric acid (sp.gr. 1·16–1·18) and evaporate again to about 15 ml, taking care to avoid localized drying out of iron salts.

Cool, add 100 ml of sulphurous acid solution (*see* note 1), mix by swirling, and heat to boiling. Boil for 2–3 min to ensure complete reduction of iron and then dilute to about 250 ml with hot water. Add a small plug of macerated paper pulp, heat to boiling, and add 5 ml of cinchonine reagent solution (10%). Boil for a further 3 min. Remove from the source of heat and allow to stand overnight.

Filter through a paper-pulp pad and wash with warm cinchonine wash solution (2%). Transfer the filter and precipitate to a platinum dish. Remove any adhering film of tungstic acid from the inner walls of the beaker by scouring with a piece of ashless paper moistened with ammonium hydroxide solution (50%), and add this to the contents of the platinum dish. Ignite at a low temperature until free from carbonaceous matter and finally at a temperature not exceeding 800° C. Cool and moisten the residue with water, then add 5 ml of hydrofluoric acid. Evaporate cautiously to dryness and again ignite at a temperature not exceeding 800° C. Cool in a desiccator and weigh (weight 1).

Mix 5 g of anhydrous sodium carbonate (*see* note 2) with the tungstic oxide residue in the platinum dish and fuse at 1000° C for 5 min. Cool and extract by boiling with 100 ml of water then digest at incipient boiling for 1 h to coagulate precipitated iron and titanium oxides. Filter through a paper-pulp pad and wash with hot ammonium nitrate solution (2%). Dissolve any iron oxide adhering to the platinum dish by warming with a few drops of hydrochloric acid (sp.gr. 1·16–1·18), make alkaline with ammonium hydroxide solution (50%) and add to the residue on the filter. Reserve the filtrate. Transfer the residue to the platinum dish, ignite to oxide, cool in a desiccator, and weigh (weight 2). Weight 1—weight 2 = weight of $WO_3 + Cr_2O_3 + MoO_3 + V_2O_5$. Correct for chromium, molybdenum, and vanadium oxides as follows: cool the filtrate and dilute to 250 ml in a graduated flask.

Chromium—Transfer a suitable aliquot (100 ml or less) to a 400-ml squat beaker and compare the yellow colour of the chromate against a similar aliquot from the blank test to which standard potassium dichromate solution (1 ml = 0·1 mg Cr_2O_3) is added until the colours match. Calculate to chromium oxide (g of Cr_2O_3) on 2 g of sample (weight A).

Molybdenum—Dissolve 0·5 g spectrographically pure iron in accordance with the solution of sample details given in B.S. 1121: Part 34: 1955; and after fuming (note 3 of B.S. 1121: Part 34) add a 50-ml aliquot from the tungsten filtrate. Determine the molybdenum with particular reference to note 3 (ammonium citrate modification) for tungsten-bearing samples. Convert the readings to molybdenum trioxide (g of MoO_3) on 2 g of sample (weight B).

Vanadium—Transfer a 50-ml aliquot to a 400-ml squat beaker. Acidify with phosphoric acid (50%), add 5 ml excess and allow to stand for 1 h. For a comparison solution, treat a similar aliquot from the blank test in the same way but add standard potassium dichromate solution (1 ml = 0·1 mg Cr_2O_3) to give the same chromate concentration as in the test solution.

Add standard vanadotungstic acid (1 ml = 0·1 mg V_2O_5) to the comparison solution until the colour matches that of the test solution. Calculate to vanadium pentoxide (g of V_2O_5) on 2 g of sample (weight C).

Calculation

The percentage tungsten is calculated as follows:

$$\%\ \text{tungsten} = \frac{(\text{wt. 1} - \text{wt. 2}) - (\text{A} + \text{B} + \text{C}) \times 100 \times 0{\cdot}793}{\text{wt. sample}}$$

where wt. (1) = wt. platinum dish + WO_3 + Fe_2O_3 + TiO_2 + Cr_2O_3 + MoO_3 + V_2O_5
where wt. (2) = wt. platinum dish + Fe_2O_3 + TiO_2
" " A = Cr_2O_3
" " B = MoO_3
" " C = V_2O_5

Notes

(1) The use of a large excess of sulphurous acid in this way ensures rapid and efficient reduction of ferric iron. (2) A blank should be carried through from the fusion stage. Fuse 5 g anhydrous sodium carbonate and continue as in 'Procedure.'

Screening Blast-furnace Burden Materials

By H. N. Wilkinson, B.Sc.(Eng.),

and E. E. Farmer

SCREENING IS THE METHOD ADOPTED for sizing burden materials before charging into the blast-furnace. It is done for one or more of the following reasons:

(i) To remove fine particles and ensure the free passage of gases through the charge. This results in quicker reduction of the ore, lower coke consumption, and less blast-furnace-gas cleaning. The savings obtained must be offset against the cost of the screens and the additional handling and conveying plant. The fines are agglomerated in some way, usually by sintering.

(ii) To eliminate undersized material from the crusher (or rod mill) feed. This relieves the load and helps to prevent clogging and undue production of fines. It is generally regarded as more economical to install a screen plus crusher than the larger crusher necessary without a screen.

(iii) To control the proportion of material going by a particular route through the plant. The screens then act as valves; they will be used in this way especially when high-sinter burdens are employed.

(iv) To size material for external sale. This applies only to coke.

Paper PE/I/4/58 of the Blast Furnace and Ore Preparation Plant Committee of the Plant Engineering and Energy Division of the British Iron and Steel Research Association, received on 18th June, 1958. The views expressed are the authors', and are not necessarily endorsed by the Committee as a body.

SYNOPSIS

Burden materials are sized to give increased blast-furnace output at reduced cost. A large number of different types of screen and screening surface are available for this purpose, and the construction, principles of operation, and the materials they have to handle are all briefly discussed.

Many problems arise in screening. Perhaps the greatest is 'blinding' of the screening surface apertures by lumps jamming or sticking. Other troublesome factors are the widely varying properties of iron ores and the extreme abrasiveness of coke and sinter. Site conditions often add to the difficulties. Solutions are suggested where possible. 'Blinding' can be partly reduced by imparting a sufficiently vigorous action to the screen, whilst with iron ores suitable preparation of the material is of great assistance.

It is concluded that the best modern screening practice could with advantage be more universally adopted, while some aspects of the subject require further investigation. 1595

A great deal of published information is available on various aspects of screening, and in particular the work of Taggart[1] should be mentioned. This paper gives as complete a picture as possible of the practical problems involved when screening in ore and coke preparation plants and the ways in which some of these problems might be solved. Information has been obtained from a variety of sources including published articles, visits to iron and steelworks, gasworks, coal handling plants, and discussions with manufacturers of screening and allied equipment.

Table I

VIBRATING SCREENS WITH POSITIVE ECCENTRIC DRIVE AND GYRATORY MOTION

Manufacturer	Screen	Vibrations	Screen Angle to Horizontal, °	Screening Surface Normally Supplied	Maximum Size Available, ft	Method of Mounting
The General Electric Co. Ltd.	1 Gyrex heavy type	Fixed between ¼-in. amplitude at 625 c/min and ½-in. amplitude at 1000 c/min	Variable, 0–30, normally about 18	Woven wire mats	6 × 16	Base rigidly mounted on floor structure, but can be suspended by hanger rods if required
International Combustion Products Ltd.	2 Ty-rock	Fixed between roughly ¼-in. amplitude at 800 c/min ½-in. amplitude at 1050 c/min and ¼-in. amplitude at 2500 c/min	Variable, normally about 20*	Woven wire mats	6 × 16	Main bearings supported by rubber blocks on base, which is normally cable suspended but can be rigidly mounted on floor structure
Lockers (Engineers) Ltd.	3 Titan	Amplitude fixed, normally at ¼ in. Speed fixed between 750 and 1200 c/min, normally about 1000 c/min. Occasionally ½-in. amplitude at lower speed	Variable, 5–25, normally about 20*	Bars, welded rod or woven wire mats, or perforated plates	5 × 13	Normally cable suspended, sometimes from feed end only with pivot bearings at discharge end
Niagara Screens (Great Britain) Ltd.	4 Niagara	Amplitude fixed, normally at ¼ in. Speed fixed between 900 and 1250 c/min	Variable, normally about 20*	Woven wire mats	5 × 13½	Normally supported on pivot bearings at discharge end, suspended by rods from spring mountings at feed end. Other methods available if required
Pegson Ltd.	5 Pegson-Telsmith heavy duty	Amplitude fixed, speed fixed between 875 and 1000 c/min (5 ft × 6 ft deck) and between 650 and 800 c/min (5 ft × 12 ft deck)	Fixed at about 20	Heavy welded-bar grid	5 × 12	Main bearings supported by rubber blocks on base, which is rigidly mounted on floor structure

* Variable only if rod or cable suspended.

Details common to all screens: Circular motion, direction of rotation easily reversed. Counterweights fitted to reduce vibrations transmitted to supporting structure. Screen deck flexibly supported on base. Screening surface flat or transversely arched. Single- or double- (sometimes multi-) deck units available.

BLAST-FURNACE BURDEN MATERIALS

The four materials used in the blast-furnace burden are iron ore, sinter, coke, and limestone. The properties of, and sizings required for, each will be dealt with separately.

Iron ore

There are many different types of iron ore, but in the U.K. a rough subdivision can be made into home and imported ores. Most home ores have a low iron content and contain a high proportion of gangue. Consequently they are often of a sticky nature owing to the presence of clay and moisture. Coming largely from open-cast sites, and sometimes remaining for days in open railway wagons, the moisture content of the ore may be as high as 20–22% in wet weather, but the figure varies considerably. Really difficult screening conditions due to wet ores may be experienced for only one or two months during the year. The bulk density averages 90 lb/ft³. As received into the works, lumps range in size up to 40-in. cubes. Many of the lumps are very friable or consist of fines balled together. These are carried over the screens but later break up owing to rabbling etc. on the way to the blast-furnace. Another difficulty is that fines often adhere to the larger lumps, with similar results.

Imported ores generally have a high iron content. As received into this country they tend to be either hard and lumpy, or pre-crushed to fines, in which case screens can be by-passed. Lump size is rarely above 10 in., and the majority is — 6 in.[2] The ores are often dry and easy to screen compared with those of home origin, but sometimes sticky ores with high moisture and fines contents are received. The average bulk density is 150 lb/ft³, but may be as high as 200 lb/ft³. All ores, home and imported alike, are abrasive.

As a rough guide the first main sizing performed by screens, following scalping* and crushing, is at about 2½ in. for home ores and 1½ in. for imported ores. Final screening is at about ⅜–½ in. This size represents probably the most reasonable compromise between the lower limits of size that can be tolerated in the blast-furnace and the smallest mesh which can be maintained without undue blinding[3] or clogging of the apertures of the screening surface. With a sticky ore this lower limit may have to be increased to ⅝ in. or even ¾ in. in winter. With a dry ore final screening at $\frac{5}{16}$ in. or even ¼ in. may be possible. The final sizing may also depend to some extent on the sinter-plant capacity available.

Alternatively, the second sizing can be made at about ¾ in. and tertiary crushing used to bring the size down to ¼ in., when much better quality sinter results. To get satisfactory operation of the crusher, extra screening at ¼ in. will also be necessary and this may present a difficult problem.

Sinter

Perhaps the most important property of this material from the viewpoint of screening is its extreme abrasiveness. It may have to be screened either hot or cold. Cooling is effected by air or water; if water is used the material will also contain corrosive liquor. The bulk density will be rather less than that of the

* Scalping is a process of coarse sizing for removing the larger lumps of material.

ore from which it was made. Screening is carried out at $\frac{1}{4}$–$\frac{3}{8}$ in. A coarse sizing is sometimes made first to prevent the larger lumps from damaging the fine mesh. In addition a portion of the oversize in the range $\frac{5}{8}$–1 in. may have to be screened out to provide a hearth layer for the sinter machine.

Coke

This material, like sinter, is very abrasive. The particles are rough and full of voids, and fines do not separate out easily. The bulk density is low, being only 28 lb/ft^3, and so the screens must be large in relation to the tonnage handled. Breeze and fines are

Table II

VIBRATING SCREENS WITH OUT-OF-BALANCE DRIVE AND GYRATORY MOTION

Manufacturer	Screen	Vibrations	Screen Angle to Horizontal, °	Screening Surface Normally Supplied	Maximum Size Available, ft	Method of Mounting
Allis-Chalmers Great Britain Ltd.	6 Aero-Vibe	Amplitude fixed, maximum $\frac{1}{4}$ in. Speed fixed between 1450 and 1750 c/min	Variable, 0–30, normally 18–30*	Woven wire mats or perforated plates	4 × 10	Normally cable suspended, can be flexibly mounted on floor structure
	7 Ripl-Flo, standard heavy duty	Amplitude fixed between $\frac{1}{16}$ and $\frac{7}{16}$ in. Speed fixed between 700 and 950 c/min	Variable, 0–30, normally 18–30*	Woven wire mats or perforated plates	6 × 16	
	8 Ripl-Flo, extra heavy duty	Amplitude fixed, speed fixed between 700 and 800 c/min	Variable, 12–18*	Longitudinal bars or perforated plates	6 × 16	
Denver Equipment Co., Ltd.	9 Denver-Dillon	Amplitude fixed, speed fixed between 600 and 1250 c/min	Variable, normally about 20	Woven wire mats	6 × 14	Suspended by rods from spring mountings
Moxey Ltd.	10 Moxey-Dillon	Amplitude fixed, maximum $\frac{1}{16}$ in., normally about $\frac{1}{32}$ in. Speed fixed between 600 and 1250 c/min, normally 1100–1250 c/min	Variable, normally about 22	Welded rod or woven wire mats, or perforated plates	6 × 14 5 × 14 for dense materials	Suspended by rods from spring mountings
The General Electric Co., Ltd.	11 Eliptex	Elliptical motion at 45° to screen surface produced by geared counterweights. Amplitude fixed at $\frac{7}{16}$ in., speed fixed at 1000 c/min	Normally horizontal sometimes slightly inclined	Woven wire mats	6 × 16	Cable suspended or spring mounted on floor structure
	12 Vibrex, style MS	Amplitude variable, normally about $\frac{1}{4}$ in. Speed fixed at 1800 c/min	Variable, 0–20	Woven wire mats	4 × 10	Screen deck flexibly supported on base frame which is normally mounted rigidly on floor structure: can be cable suspended
W. J. Jenkins and Co., Ltd.	13 Viking	Amplitude variable, speed fixed at 1700 c/min	Variable, 5–30	Welded rod or woven wire mats secured by wedges	3½ × 7½	Screen deck supported by Silentblocs on base which is rigidly mounted on floor structure
Nordberg Manufacturing Co.	14 Symons rod deck	Not strictly gyratory motion over entire screen surface (see Method of mounting). Amplitude variable by adjusting nut, speed fixed at 875 c/min	Fixed: contoured screening surface	Spring-steel longitudinal rods	5 × 8	Screen deck flexibly hinged to base frame at feed end, spring supported at discharge end where vibrator unit is located. Base rigidly mounted on floor structure
	15 Symons rod grizzly	(See above) Speed fixed at 865 c/min	Fixed: contoured screening surface	Spring-steel longitudinal rods	4½ × 8	
	16 Symons bar grizzly	(See above) Speed fixed at 850 c/min	Fixed: contoured screening surface	Double-tapered longitudinal bars	3½ × 5	Screen deck sprung supported on base frame at feed end where vibrator unit is located, flexibly hinged at discharge end. Base rigidly mounted on floor structure.
Pegson Ltd.	17 Vibro-King	Amplitude variable, speed fixed between 1036 and 1267 c/min (3 ft × 8 ft deck) and between 860 and 1000 c/min (5 ft × 12 ft deck). Automatic spring-balanced counterweights to give smooth operation at low or critical speeds	Fixed at about 20	Welded rod or woven wire mats, or perforated plates	5 × 12	Screen deck spring supported on base frame which is rigidly mounted on floor structure
Carl Schenck Maschinenfabrik GmbH	18 Universal	Amplitude variable $\frac{1}{16}$–$\frac{1}{4}$ in., speed normally fixed at 1500 c/min but variable speed drive sometimes fitted	3–15	Mats or perforated plates	5 × 14½	Screen deck spring supported on base frame which is rigidly mounted on floor structure

* Variable only if rod or cable suspended

Details common to all screens: Generally circular motion, direction of rotation easily reversed. Amplitude varied by changing out-of-balance weight (Nos. 11–18 only), speed can be altered by changing drive-pulley size. Screening surface flat or transversely arched. Single- or double- (sometimes multi-) deck units available. (Nordberg screens single-deck only)

Table III

VIBRATING SCREENS WITH RECTILINEAR MOTION

Manufacturer	Screen	Vibrations	Screen Angle to Horizontal, °	Screening Surface Normally Supplied	Maximum Size Available, ft	Method of Mounting
Allis-Chalmers Great Britain Ltd.	19 Low-Head	Produced by geared counterweights. Vibrations at 45° to screen surface. Amplitude and speed fixed	Normally horizontal but may be varied 0–10	Woven wire mats or perforated plates	6 × 20	Cable or rod suspended or flexibly mounted on floor structure
Carl Schenck Maschinenfabrik GmbH	20 Vibro-Screen feeder	Produced by geared counterweights contained in exciter unit. Vibrations, normally linear and inclined to screen surface, can be made gyratory by adjusting exciter. Amplitude variable $\frac{1}{16}$–$\frac{1}{4}$ in. Speed normally fixed between 1000 and 1500 c/min, but variable-speed drive sometimes fitted	Variable, 0–15 if cable suspended	Mats or perforated plates	9 × 19½	Cable suspended or flexibly mounted on floor structure
The General Electric Co., Ltd.	21 Sherwen	Electromagnetic type. Vibrations at 45° to screen surface. Amplitude variable while screen is in motion, frequency fixed at 3000 c/min	Variable	Woven wire mats	60ft² per deck	Suspended by rods from spring mountings
Lockers (Engineers) Ltd.	22 Locker-Traylor	Electromagnetic type. Vibrations at fixed angle to screen surface. Amplitude variable while screen is in motion, frequency fixed at 3000 or 6000 c/min	Variable	Woven wire mats, longitudinally arched	4 × 15	Suspended by rods from spring mountings or flexibly mounted on floor structure
International Combustion Products Ltd.	23 Hummer	Electromagnetic 'impact' type. Amplitude variable while screen is in motion, frequency fixed at 1800 or 3000 c/min	Variable, normally about 33	Woven wire mats	4 × 10 (two vibrator units in series) 8 × 5 (two vibrator units in parallel)	Screen frame rigidly mounted on floor structure
Rheinische Werkzeug-U Metallwarenfabrik GmbH	24 Rhewum	Electromagnetic 'impact' type with multi-vibrator units. Amplitude variable while screen is in motion, basic frequency fixed at 6000 c/min with strong harmonics	Variable, sometimes as steep as 45	Woven wire mats of carbon or stainless spring steel	Roughly 7 × 8½	Screen frame held rigidly by supporting stand which is mounted on floor structure

readily formed, and therefore coke must not be agitated more than necessary during handling and screening. Moist, fine coke is also rather sticky, and since the particles are rough and jam easily, screening at the small sizes is doubly difficult. The main size separation for blast-furnace coke is usually at 1¼–1½ in. Undersize is screened to give 'nuts,' 'peas,' etc. for external sale. Minus ⅜-in. coke (i.e. breeze) is crushed to ⅛ in. in rod mills for the sinter plant. To reduce the load on these mills fines below ⅛ in. are first removed.

Limestone

The use of limestone is unnecessary if the proportions of the various ores can be chosen to give a self-fluxing burden. However, when limestone must be used, final screening is done at about ⅜ in. This does not present any problems additional to those with a dry ore and will not therefore be considered separately.

SCREENING PRINCIPLES

Facts and figures relative to the technique of screening cannot be put in the guise of a formula for determining the ideal screen in a particular application. However, certain principles which help towards good screening will be obvious from a brief analysis of the operation.

A screen functions by presenting apertures of the required size to the particles of material being handled. In addition the material must pass along the screening surface, and this movement may be effected by gravity or by a vibratory action or by both. The material must flow along the surface fast enough to give a reasonable capacity, yet slowly enough for each particle to come into contact with apertures in the right manner as often as possible. When a bed of material of some considerable depth is presented to the screen, large and fine particles are likely to be mixed indiscriminately. Provided the material is not too sticky, any movement of the material will cause rearrangement. The finer particles will find their way to the bottom of the bed and the large lumps to the top. This process is known as stratification and it is essential for efficient screening. This explains why sticky materials do not screen well, even if means are found for preventing blinding. While sufficient agitation of the bed is necessary to ensure rapid stratification, excessive movement defeats this end and must be avoided.

It follows that screening takes place in two stages. First, the bed of material is stratified and the bulk of the fines passes through the apertures near the feed end. When the bed has been reduced greatly in thick-

ness, the second stages takes place; namely, individually presenting the particles which are only just undersized to the apertures. This will happen over the remainder of the screening surface.

SCREENING EFFICIENCY

One of the most important factors influencing the efficiency of screening is the proportion of particles of nearly the correct size in the feed. The slightly

Table IV

MISCELLANEOUS SCREENS

Manufacturer	Screen	Vibrations	Screen Angle	Screening Surface Normally Supplied	Maximum Size Available	Method of Mounting
Robert Cort and Son Ltd.	25 Reading	Gyratory motion at discharge end, reciprocating motion at feed end. Amplitude and speed fixed at about 300 c/min. Counterweights fitted to reduce vibrations transmitted to supporting structure	Fixed at slight incline	Perforated plates secured by wedges	3 ft 6 in. wide	Screen deck supported on base frame by eccentric drive unit at discharge end, suspended by rocking links at feed end. Base rigidly mounted on floor structure
	26 Caesar	Gyratory motion at feed end, reciprocating motion at discharge end. Amplitude fixed between $\frac{3}{4}$ in. and $1\frac{1}{2}$ in., speed fixed between 220 and 300 c/min. Counterweights fitted to reduce vibrations transmitted to supporting structure	Fixed at slight incline	Perforated plates secured by wedges	7 ft wide	Screen deck supported on base frame by eccentric or crankshaft drive unit at feed end, suspended by rocking links at discharge end. Base rigidly mounted on floor structure
	27 Superimposed	Twin-deck version of the Caesar	Fixed at slight incline	Perforated plates secured by wedges	7 ft wide	Each screen deck supported on base frame by twin double-eccentric or 4-throw crankshaft drive unit at feed end, suspended by separate pairs of rocking links at discharge end. Base rigidly mounted on floor structure
	28 Spartan	Flat opposed reciprocating tray type. Amplitude fixed, speed fixed at 310 c/min	Fixed horizontal	Perforated plates secured by wedges	6 ft × 35 ft	Tray (similar to screen deck) suspended by steel rocking links within base frame which is rigidly mounted on floor structure
W. J. Jenkins and Co., Ltd.	29 Consort	Flat opposed reciprocating tray type. Amplitude fixed at 1 in., speed fixed between 390 and 410 c/min	Fixed horizontal	Welded rod or woven wire mats, or perforated plates secured by wedges	4 ft 10 in. × 40 ft	Tray flexibly supported by plastic-bonded laths on base frame which is rigidly mounted on floor structure
Nordberg Manufacturing Co.	30 Symons type F	Reciprocating motion at 30° to horizontal produced by eccentric drive unit. Amplitude fixed between $\frac{3}{4}$ in. and 1 in., speed fixed between 700 and 750 c/min. Balancing frame to reduce vibrations transmitted to supporting structure	Fixed horizontal	Welded rod or woven wire mats, or perforated plates	5 ft × 16 ft	Screen deck flexibly supported by steel strips on base frame which is rigidly mounted on floor structure. Base can also be suspended if required.
Robert Cort and Son Ltd.	31 Cort-Krupp type G.U.	Resonance type. Inclined oscillatory motion at fixed angle of 30°, 45°, or 60° to screen surface. Amplitude variable $\frac{3}{4}$–$1\frac{1}{2}$ in., speed fixed between 500 and 1000 c/min	Fixed horizontal or slightly inclined	Woven wire mats or perforated plates	5 ft 11 in. × 18 ft	Screen deck connected to balance frame by flexible laths. Relative movement restrained by rubber buffers. Balance frame mounted on rubber cushions on floor structure
W. J. Jenkins and Co., Ltd.	32 Jenkins-S.K.B.	Resonance type. Inclined oscillatory motion at fixed angle to screen surface. Amplitude variable, speed fixed between 500 and 750 c/min	Fixed horizontal or slightly inclined	Woven wire mats or perforated plates	7 ft 4 in. × 22 ft	Screen deck connected to balance frame by flexible laths. Relative movement restrained by rubber buffers. Balance frame is mounted on rubber cushions on floor structure
West's (Manchester) Ltd.	33 West-Flamrich	Resonance type. Inclined oscillatory motion at fixed angle of 30° or 45° to screen surface. Amplitude variable $\frac{1}{2}$–$1\frac{1}{2}$ in. Speed fixed 580 to 700 c/min	Fixed horizontal or slightly inclined	As required	7 ft × 25 ft	Screen deck connected to balance frame by flexible laths. Relative movement restrained by rubber buffers. Balance frame mounted on rubber cushions on floor structure
Pegson Ltd.	34 Pegson-Humboldt	Resonance type. Inclined oscillatory motion at fixed angle to screen surface. Amplitude variable $\frac{3}{4}$–1 in., normally $\frac{7}{8}$ in. Speed fixed between 500 and 1000 c/min, normally about 700 c/min	Fixed horizontal or slightly inclined	Welded rod or woven wire mats, or perforated plates	7 ft × 20 ft	Relative movement between screen deck and balance frame restrained by rubber buffers. Both members flexibly supported on base frame mounted on floor structure

Table V
RANGE OF APPLICATION OF SCREENS LISTED IN TABLE I

Screen	Source of Information*	Country	Type of Works	Material Handled	Extent Used†	Feed Size, in.	Sizing Duty, in.	Notes
1 Gyrex, heavy duty	Known	U.K.	Iron and steel	Home and imported ores	Widely	...	4–¼, generally 2½–¼	Gas heating often applied at ¾ in. (ore) and at ½ in. (coke). Electrical heating also available
	Known	U.K.	Iron and steel	Sinter	Occasionally	...	¼	
	Known	U.K.	Iron and steel and gas	Coke	Widely	...	2½–¼, generally 1½–¼	
	Known	U.K.	Iron and steel and quarry	Limestone	Widely	...	1½–¾	
	Claimed	...	...	Blast-furnace burden, including hot sinter; coal, etc.	...	...	Coarse to fine, 8 downwards	
2 Ty-rock	Claimed	...	...	Rock, ores, coal, etc.	...	...	Coarse to medium, 10 downwards	Electrical heating available
3 Titan	Advised Claimed	U.K.	Quarry	Limestone Blast-furnace, burden etc.	...	—¾	¼ and ⅛ 6–⅛	Electrical heating at ⅛ in.
4 Niagara	Known	U.K.	Iron and steel	Ore	Occasionally	...	2–¼	
	Known	U.K.	Iron and steel	Hot sinter	Moderately	—14	½–¼	
	Advised	U.K.	Iron, gas	Coke	Moderately	...	4½ downwards	...
	Advised	U.K.	Quarry	Limestone	Widely	—6	2½–¾	
	Claimed	...	...	Blast-furnace burden, coal, gravel, etc.	...	...	Most ranges	
5 Pegson-Telsmith heavy duty	Advised	U.K.	Quarry	Limestone, etc.	Widely	...	Scalping ahead of primary and secondary crushers	...

* 'Known' indicates that the information comes from a reliable and disinterested source, and generally the application is known to the present authors
'Advised' indicates that the information has been supplied by the screen manufacturer, but refers to specific applications
'Claimed' indicates the range of application considered suitable by the manufacturer
† 'Widely,' 'moderately,' and 'occasionally' have been applied relative to the estimated total number of applications for the duty and country quoted

oversize pieces jam in the apertures while those only slightly smaller than the apertures pass through with difficulty, and therefore slowly. It is usually the maximum, rather than the minimum, projected surfaces of the particles which are parallel to the plane of the screen, but agitation helps to turn them over.

A formula for determining the efficiency of a screen is as follows:

$$\text{Efficiency } E = \frac{10{,}000\ U}{u\ F}$$

where U = Tonnage passing through screen
F = Feed in tons
u = Percentage undersize in feed as determined by test sieving.

This definition does not take into account the effect of near-size particles. Gaudin[4] suggests that efficiency should be based on the ratio of 'difficult' particles taken out by the screen to 'difficult' particles in the feed. The range covered by the word 'difficult' would, of course, have to be defined. In other words, efficiency is a function of the material being screened

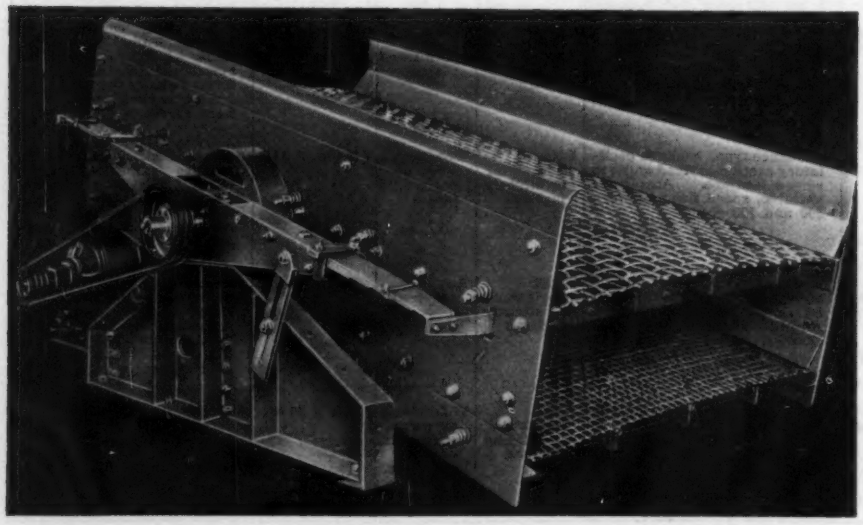


Fig. 1—Positive eccentric drive 'Gyrex' screen

as well as of the screen, so that the efficiency figure for the screen has no meaning unless the material is quoted.

Optimum efficiency will be obtained when the screen is running neither overloaded nor nearly empty. In the first case the bed of material may not become completely stratified before being discharged, while on a lightly loaded screen the lumps bound along the surface too fast. As a rough guide, a screen is handling its maximum tonnage of dry material at reasonable efficiency when the apertures can just be seen within 1 ft of the discharge end. A rule-of-thumb figure for

Table VI

RANGE OF APPLICATION OF SCREENS LISTED IN TABLE II

Screen	Source of Information*	Country	Type of Works	Material Handled	Extent Used*	Feed Size, in.	Sizing Duty, in.	Notes
6 Aero-Vibe	Advised	U.K.	Colliery	Coal	...	...	...	
	Claimed			Blast-furnace burden, crushed stone, etc.		4 max	Medium to fine, 1½ in. to 35 mesh	Recently introduced in U.K.
	Claimed			Coal		6 max	Medium to fine, 1½ in. to 35 mesh	
7 Ripl-Flo, standard heavy duty	Advised	U.K.	Quarry	Limestone	1 application	— ¾	¾	Recently introduced in U.K.
	Known	U.K.	Colliery	Coal			¾–⅛	
	Claimed			Blast-furnace burden, coal, gravel, etc.			Coarse to fine	
8 Ripl-Flo, extra heavy duty	Claimed	...	...	Ore	...	36 max	Scalping 10–4	...
	Claimed			Ore		16 max	Down to ⅛	
9 Denver-Dillon	Advised	U.K.	Gas, cement	Coke	Moderately	...	...	...
	Advised	U.K.	Quarry	Limestone	Occasionally		...	
	Claimed			Coal, coke, gravel, etc.			Medium to fine at 1½ downwards, de-dusting	
10 Moxey-Dillon	Known	U.K.	Iron and steel	Home and imported ores	1 application	— 6	2½ and 1, ½ tried	Gas beating often applied at ½ in. (sticky ore) and at ¼ in. (wet breeze)
	Advised	U.K.	Iron and steel	Coke	4 applications	...	...	
	Claimed			Ore		6 max	Down to ¼ (sticky), ⅛ (dry)	
	Claimed			Limestone		6 max	Down to ½ in.	
	Claimed			Coal, coke, etc.		8 max	Down to ½ in.	
11 Eliptex	Advised	U.K., U.S.A.	Mine, colliery	Ore, coal	Moderately	...	2½ downwards	Recently made available in U.K.
	Claimed						Medium and especially fine	
12 Vibrex	Advised	U.K., U.S.A.	General	All classes	Moderately	8 max	Medium to fine	...
	Claimed		General	All classes		8 max	Suitable for most Gyrex applications	
13 Viking	Claimed			Coke	...	...	De-breezing at about ¼ or ⅛	...
	Claimed			Coal			De-dusting at about ½	
14 Symons rod deck	Known	U.K.	Iron and steel	Home and imported ores	Moderately	...	¾–½	
	Known	U.K.	Iron and steel	Sinter (sometimes hot)	Moderately		1–½, occasionally at ¼	...
	Advised	Germany		Ore			¾	
	Claimed			Dry and sticky ores, rock, etc.			Specially adapted to sizing at comparatively small openings	
15 Symons rod grizzly	Known	U.K.	Iron and steel	Home and imported ores	Moderately	...	1½–¾	Introduced about 5 years ago
	Claimed			Wet and sticky ores, rock, etc.			Scalping, and 4–½	
16 Symons bar grizzly	Known	U.K.	Iron and steel	Home and imported ores	Moderately	...	4–1½	...
	Known	U.K.		Clinker	Moderately		Scalping at 6	
	Claimed			Most wet and sticky materials			Sizing and scalping at 1½ upwards	
17 Vibro-King	Advised	U.K.	General	Stone, ore, coal, coke, gravel, etc.	Moderately	...	Medium to fine	Introduced about 3 years ago
18 Universal	...	...	...	...	...	...	...	No information available

* See footnote to Table V

Table VII
RANGE OF APPLICATION OF SCREENS LISTED IN TABLE III

Screen	Source of Information*	Country	Type of Works	Material Handled	Extent Used*	Feed Size, in.	Sizing Duty, in.	Notes
19 Low-Head	Advised Claimed	U.S.A.	Iron and steel	Ore Blast-furnace burden, coal, etc.	Widely	−5	2½–¼ Medium to fine, 2½ downwards	...
20 Vibro screen feeder	Known	U.K.	Iron and steel	Imported ore	Moderately	...	4–¾, generally 1½–¾	Gas heating at ¾ in.
	Known	U.K.	Iron and steel	Sinter (sometimes hot)	Moderately		½–¾	
	Known	U.K.	Iron and steel	Coke			¾ and ½	Electrical heating at ½ in.
	Claimed			Blast-furnace burden, etc.			Medium to fine	
21 Sherwen	Known Claimed	U.K.	Iron and steel	Ore Coal, cement, etc.	Occasionally	...	1½–¼ Medium to fine, especially at ½–¼	...
22 Locker-Traylor	Claimed	...	...	...	...	...	Medium to fine	...
23 Hummer	Claimed	...	...	...	...	...	All types of screening except coarse, but mainly for fine	Electrical heating available
24 Rhewum	Advised Advised Advised Claimed	Europe Europe Europe	Iron and steel Iron and steel Iron and steel	Ore (12% moisture) Sinter Coke (20% moisture) Especially suitable for difficult materials	...	 −¾	¾–¼ ... ¼ Fine	No heating used in any application

* See footnote to Table V

the speed at which the material should flow is about 1 ft/s. It follows that when two screening lines in parallel are available and conditions of light loading exist, greater efficiency as well as more economical working will result if all the material is handled on one line.

A subject closely related to efficiency is screen area. If 100% screening efficiency were required, then an infinite area would be necessary. In practice, of course, a lower efficiency is accepted, and the screen area required will depend largely on the percentage of near-size capacity, increase in length gives greater efficiency.

TYPES OF SCREEN

It is not intended in this paper to give a thorough description of all the different types of screen which might be suitable for an ore or coke preparation plant. Published information and manufacturers' literature are readily available. A brief survey of only the main types follows, and further details are given in Tables I, II, III, and IV. The range of application of these screens is covered by Tables V, VI, VII, and VIII. It should be emphasized that whilst these tables cover the majority of screens commonly used in the iron and steel and allied industries in the U.K., a number may have been inadvertently omitted. Moreover the details of construction listed are only those applying to general duties. When need arises some manufacturers are willing to supply a screen which they assert is 'tailor-made' for the job. Screens typical of their class are shown in Figs. 1–12.

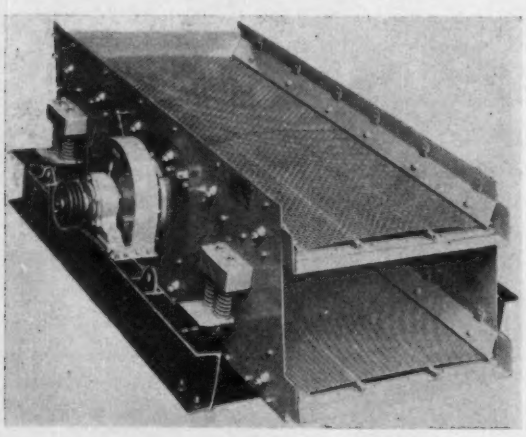


Fig. 2—Positive eccentric drive 'Niagara' screen

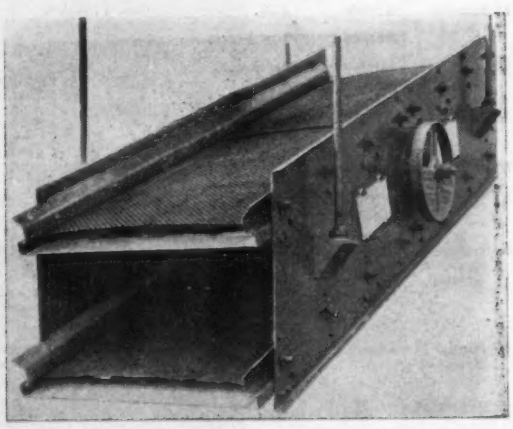


Fig. 3—Out-of-balance drive 'Dillon' screen

Table VIII

RANGE OF APPLICATION OF SCREENS LISTED IN TABLE IV

Screen	Source of Information*	Country	Type of Works	Material Handled	Extent Used*	Feed Size, in.	Sizing Duty, in.	Notes
25 Reading	Known	U.K.	Iron and steel, gas	Coke	Moderately in iron and steel	...	De-breezing ¼	...
	Claimed			Coke			De-breezing	
26 Cæsar	Claimed			Coke			Scalping and sizing	...
27 Super-imposed	Known	U.K.	Iron and steel, gas	Coke	Moderately in iron and steel	...	2–¼	...
	Claimed			Coke			...	
28 Spartan	Known	U.K.	Gas	Coke	Widely	...	1¼–¼	...
	Claimed			Coke			Medium to fine	
29 Consort	Known	U.K.	Gas	Coke	Widely	— 2½	1¼–¼	...
	Claimed			Coke		6 max	Medium to fine, 3–¼	
30 Symons, type F	Advised	U.K.	Iron and steel	Ore	Occasionally	...	¼	...
	Advised	U.K.	Iron and steel	Coke	Occasionally		1¼–¼	
	Claimed			Limestone, coal, gravel, etc.			Medium to fine, and de-dusting	
31 Cort-Krupp	Claimed	...	...	Ore	...	4 max	2–¼	Recently introduced in U.K.
	Claimed			Coal, coke, limestone, etc.		8 max	Down to ¼	
32 Jenkins-S.K.B.	Claimed	...	...	Most materials	...	...	Medium to fine	Recently introduced in U.K.
33 Flamrich	Advised	U.K.	Colliery	Coal (10% moisture)		— 8	4–¼	Recently introduced in U.K. Electric heating applied at ⅛ in.
	Advised	France	Iron and steel	Ore		— 4	¼ and ⅛	
	Advised	Germany		Coal	...	— 5	½–⅛	
	Claimed			Ore, coal, coke, gravel, etc.		24 max	Coarse, medium, and fine	
34 Pegson-Humboldt	Advised	Germany	Iron and steel	Blast furnace burden	Occasionally	...	Down to ½ for sticky ore	Recently introduced in U.K.
	Advised	Germany	Colliery	Coal	Widely		Down to ⅛	

* See footnote to Table V

Static-bar, Moving-element, and Revolving Screens

The static bar screen consists simply of an inclined grid composed of longitudinal bars and cross ties. It is sometimes used to remove fines from coke fed into the blast-furnace bunkers. If the bars are closely spaced they blind easily and in any case this form of screen is inefficient. Much of the following section dealing with screening surfaces will also apply here.

There are two types of moving-element screen commonly used in iron and steelworks: the drop-bar feeder and the roll grizzly. Both give useful service as scalpers before the main ore crushers. The plate grizzly, similar in principle to the roll grizzly, is occasionally used for sizing coke. Its efficiency is not high and whilst adequate for scalping, it should not be employed for final sizing.[5]

The revolving cylinder or trommel type of screen has a low capacity for its size and is now obsolete.

Reciprocating Screens

The modern type consists of a flat horizontal tray or deck fitted with a screening surface and supported on flexible laths or rocking links, which are inclined backwards. The deck is given a reciprocating movement by a suitable mechanism; the motion is upward at the end of the forward stroke and sharply downwards at the beginning of the backward stroke with the result that the screen drops away from under the load and the material moves ahead in a series of jumps.

In order to minimize vibrations transmitted to the supporting structure, two screen decks may be mounted on opposite sides of a driving shaft with eccentrics at 180°. This is known as the 'flat opposed reciprocating tray screen' (*see* Fig. 11). The screening surface is in a number of sections, each having a progressively larger aperture size towards the discharge end. The screen is used mainly for sizing coke in the middle ranges for external scale and it has the following advantages[5]:

(i) It conveys as it screens and can therefore be used to feed the various size grades to appropriate hoppers without additional conveyors

(ii) The headroom required for the installation is small

(iii) Maintenance is simple as the drive comes from eccentrics mounted above the screen, and all parts requiring attention are easily accessible

(iv) The motion does not cause friable material to be broken unduly.

The limitations are:

(i) Sizing is by eliminating the smallest particles first and larger particles subsequently. The whole of the feed is therefore taken on the finest mesh with consequent heavy wear, unless it is protected by an upper scalping deck.

(ii) Balancing is never complete and vibrations may be communicated to the supporting structure.

(iii) Capacity is low for the size of screen compared with vibrating types, described later.

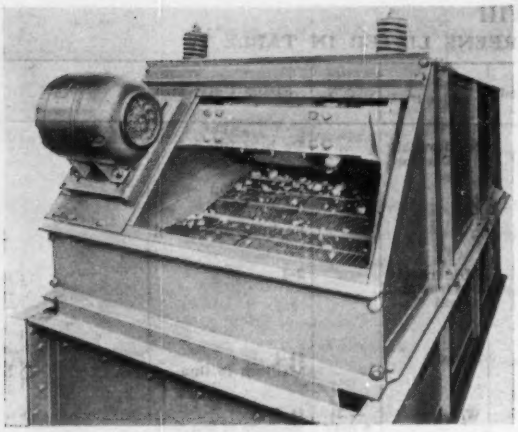


Fig. 4—Out-of-balance drive 'Rod Deck' screen

(iv) The screening action is not sufficiently vigorous entirely to prevent blinding of the smallest apertures.
(v) It is not suitable for treating clayey ores because of the readiness with which the clay balls.[1]

Vibrating Screens

This type consists of a screening surface, usually stretched taut over a rectangular frame, inclined to the horizontal, and caused to vibrate with small amplitude and at a comparatively high frequency.

There are two types in common use: in one the whole screening surface is given a gyratory movement or throw which may be caused either by a positive eccentric drive (Figs. 1 and 2) or by an out-of-balance mechanism (Figs. 3, 4, and 5). This motion is usually more or less circular. Direction of throw may be either forwards or backwards, and on this choice will depend to some extent the angle of inclination of the screening surface. Counterbalance weights or flexible mountings, whichever are appropriate, reduce the vibrations transmitted to the supporting structure. In some cases it will be possible to use both methods. In the other type of screen a rectilinear movement is imparted to the screening surface, which can be done in a number of ways. One method is to have a

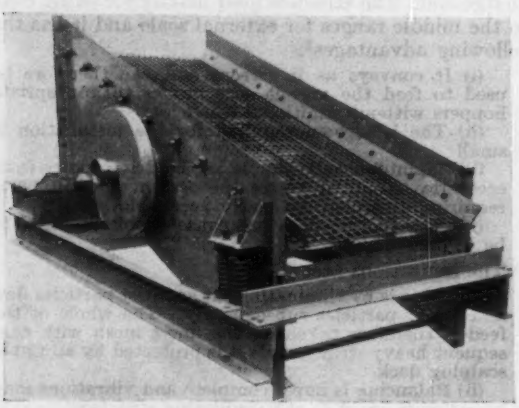


Fig. 5—Out-of-balance drive 'Vibro-King' screen

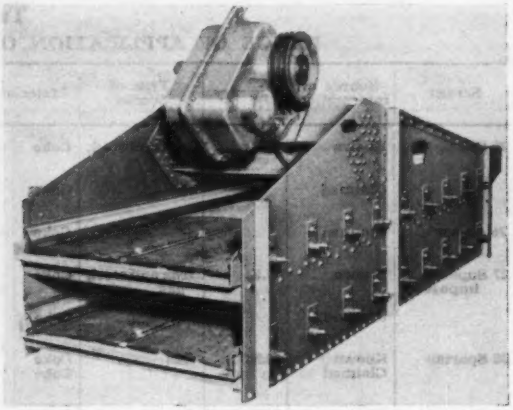


Fig. 6—'Low-Head' rectilinear-motion vibrating screen

vibrator, usually electromagnetic, attached directly to the screen deck, which is flexibly mounted (Fig. 7). An alternative arrangement is to apply vibrations normal to, and at the centre of or at selected points on, the screening surface. The edges of this are firmly fixed to the supporting frame. The effect is similar to the pummelling of a diaphragm and the screen is known as the 'impact' type (*see* Figs. 8 and 9).

In addition there are various miscellaneous screens which cannot be rigidly classified. One type, for instance, has a gyratory motion at the feed end whilst the other end is suspended by rocking links and reciprocates (Fig. 10).

Vibrating screens are the most widely used of all the various types, and they have the following advantages:

(i) They are suitable for sizing either by selection (i.e. removing fines first) or by rejection (i.e. removing large lumps first).
(ii) The vibrating mechanism can usually be completely enclosed and protected against dirt. However, electromagnetic vibrators have a tendency to collect magnetic materials and are not always popular in iron and steelworks.

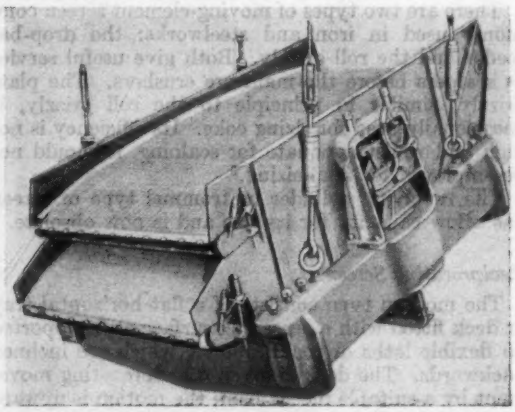


Fig. 7—Locker-Traylor electromagnetic (non-impact) screen

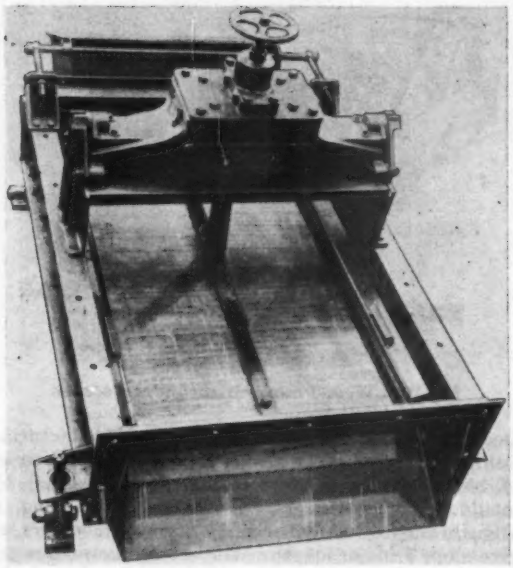


Fig. 8—Electromagnetic (impact) 'Hummer' screen

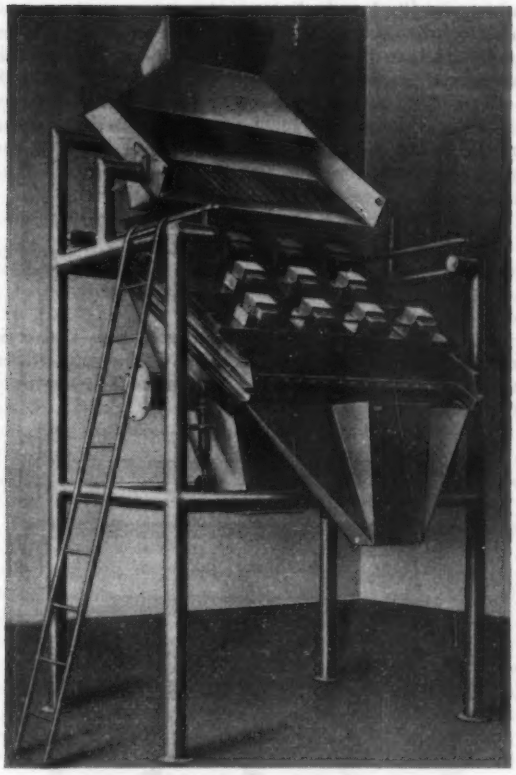


Fig. 9—Electromagnetic multi-vibrator (impact) 'Rhewum' screen

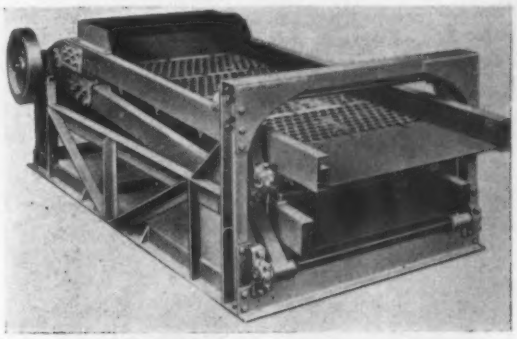


Fig. 10—Superimposed screen with gyratory-reciprocating motion

(iii) The intensity of vibration may be chosen to suit the characteristics of the material being screened. The intensity of vibration is defined as the product of the frequency of vibration and the amplitude* in a direction at right-angles to the screening surface. The alteration of either of these factors is usually sufficient to achieve the required result. With some types of screen the speed can only be varied over a narrow range, since extraneous vibrations would otherwise develop.

(iv) The capacity is high for the size.

The limitations are:

(i) For material to flow the screen must be at an angle to the horizontal, which is liable to increase the overall height of the plant. Alternatively, the motion must be either elliptical or rectilinear, at an angle to the screening surface, and with a forward throw.

(ii) There is a tendency for an increase in velocity to take place as material travels down the screen surface under gravity. This can be checked by levelling the surface towards the discharge end, but the design becomes more complicated. In machines with a number of electromagnetic vibrators the velocity can be checked by separate intensity controls for different screen sections.

Resonance Screens

Screens of this type have been introduced into the U.K. only within the last few years. The Cort–Krupp model will serve as an example, but in principle all types are very similar. They are in some respects akin to the flat reciprocating tray screen. The special feature is a balance frame which works in opposition to the screen deck. These two members are connected by flexible laths and relative movement is restrained by rubber buffers which act as energy absorbers. A vibrator unit, mounted on the frame, imparts a rectilinear movement to the deck; the frame is located on anti-vibration mountings. The frequency of vibration is in the range 500–1000 c/min at low amplitude. The main advantages claimed are low power consumption and an almost complete absence of vibrations transmitted to the supporting structure. In addition, the screen is easily installed, since it merely rests on rubber cushions on the floor. Intensity of vibration can be varied over a wide range without the machine becoming unbalanced. A special advantage is obtained when dealing with difficult materials. The rubber buffers stop the screening surface with a jerk

* The convention is that amplitude of vibration equals twice the maximum displacement about the mean point

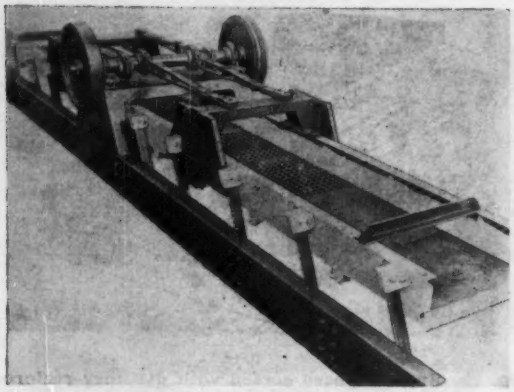


Fig. 11—Flat opposed reciprocating tray 'Consort' screen

at each end of the stroke, thereby helping to dislodge particles jammed in the mesh.

SCREENING SURFACES

The screening surface consists of a series of apertures which allow undersized material to be eliminated from the feed. The properties required are as follows:

(i) It must have good wear properties and be able to withstand abrasion and corrosion
(ii) While being sufficiently strong to carry the load, it must have as high a proportion of open area as possible
(iii) Since wear occurs, suitable arrangements must be made to permit the screening surface to be changed easily and quickly
(iv) The cost should be low
(v) It should not encourage blinding by particles jamming or sticking
(vi) In some circumstances a screen surface will be required which encourages the flow of material; in others the opposite will apply. The design should be selected accordingly.
(vii) It is an advantage if it helps to spread the material evenly across the screen
(viii) The surface must be sufficiently rigid for vibrations to be transmitted from the screen frame (or energy source with the 'impact' screen) to the load.

Types of Screening Surface

Longitudinal bars—These are often fitted to vibrating screens, which are then termed 'bar grizzlys.' They are suitable only for coarse screening over about 2½ in. Heavy-section bars are the best means of ensuring a long surface life, especially when large lumps of high-density material are being handled, the only reasonable alternative being a roll grizzly. The bars tend to make the lumps travel down the screen in a set path, and there is no spreading action. The bars are usually wedge shaped and slightly tapered longitudinally to prevent lumps jamming. Although they may function in this way when new, in time the bars become worn and slightly contoured. Repairs can be made by welding. This takes time, but should not often be necessary.

Longitudinal rods—This type of screening surface, somewhat similar to the previous one, is considered applicable wherever sizing does not have to be confined to square or circular apertures. The most notable example of the use of this surface is the Symons Rod Deck Screen made by the Nordberg Manufacturing Company (Fig. 4). The screen deck consists of a series of banks of spring-steel rods held in position by moulded rubber spacers. Each rod, 23 in. long, is arched longitudinally over transverse members to give slots 7 in. in length. The main advantages are that individual rods can easily be replaced, and the proportion of open area is relatively high. A disadvantage with the Nordberg design is that the angle of inclination of the deck cannot be varied.

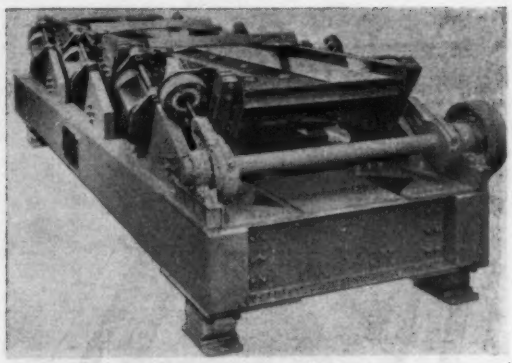


Fig. 12—West-Flamrich resonance screen

The 'Serpenti' mesh (Fig. 16) consists of a series of longitudinal rods bent in a zigzag pattern and positioned to form a square-apertured surface. Since each aperture is free to expand slightly if required, near-sized lumps should be less likely to get jammed.

Welded rod and woven wire mats or cloths—These are the screening surfaces most commonly used for sizing in the range 2½ in. downwards. The shape of the aperture may be either square or rectangular. The advantages of rectangular openings are:

(i) They increase the screen capacity by increasing the proportion of open area
(ii) If the long dimension of the slot is parallel to the direction of flow, it compensates for loss of effective aperture area due to the screen deck being set at a slope. Also, blinding is reduced.

Considering first welded rod mats (Fig. 13), it is preferable for every intersection of the rods to be welded rather than only one in four as is commonly

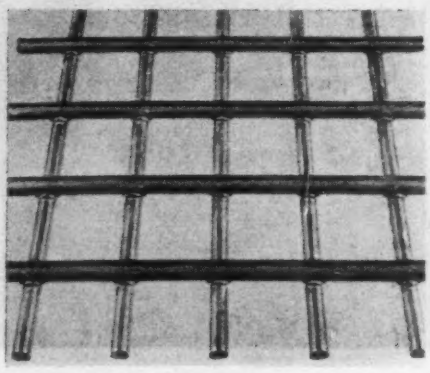


Fig. 13—Welded rod mat

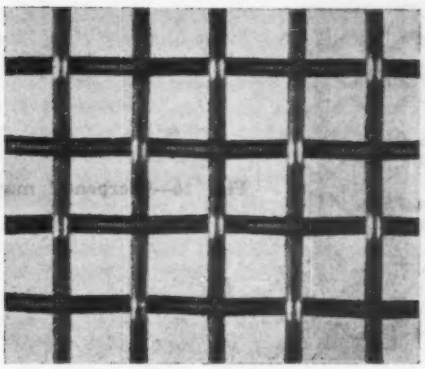


Fig. 14—Woven wire mat

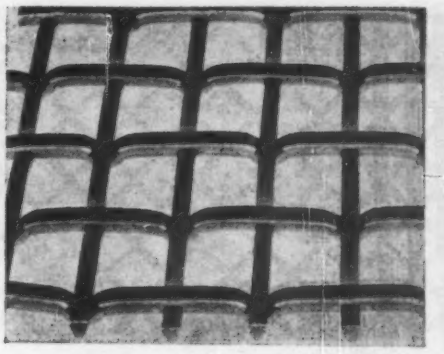


Fig. 15—' Longvita ' woven wedge-section wire mat

done. When in position on the screen either the longitudinal or transverse rods may be uppermost, which will respectively aid or retard the flow of material down the screen. Naturally, the uppermost rods will receive the greatest wear, and therefore the useful life of the mat can often be extended by turning it over. The following is the practice at one steelworks where coke is handled on a vibrating screen with a three-section mat. The longitudinal rods are uppermost on the mat nearest the feed end of the screen; this ensures material is carried away quickly, at the same time losing most of the fines. On the middle section a mat previously used at the top and having worn longitudinals is fitted with transverse rods uppermost. Besides slowing and tumbling the material, it helps to spread the material across the width of the screen. Arching the mat also helps to spread the material. On the third section the mat is again fitted with longitudinal rods uppermost. Woven wire mats (Fig. 14) are the type more commonly used. To prevent distortion under load the wires are generally ' double crimped,' and afterwards the mat may be put through rollers to flatten it. The disadvantage with this type of mat is that if a few wires snap it soon becomes limp and repairs are difficult. On the other hand welded rod mats can easily be repaired by welding, and they blind less readily. Both types of mat are usually made of round material, but square-section welded rods and wedge-section woven wires (Fig. 15) are sometimes used. Longer life is claimed for the former while the wedge-shaped wires help to prevent blinding by jamming.

The material usually employed for mat construction is mild or low-carbon steel. High-carbon, stainless, spring, or other special steels are sometimes used to obtain longer mat life. As a rough guide it is reckoned that they give double the life at double the cost, although in some cases the cost may be five to six times as much with, it is to be hoped, a proportionate increase in life. Since these special steels are often difficult to obtain, their use is only justified when mat replacement is a troublesome job, or if a corrosion problem exists. When arched, a stainless-steel rod may snap more easily.

To give a sufficiently rigid surface, mats made of rods below about $\frac{3}{4}$ in. diameter are usually tensioned, often over arched frames. This may be done by hook bolts engaging welded longitudinal edge rods, which should be of greater cross-section than those in the rest of the mat. When made of smaller-gauge wires mats often have metal strips down the sides which are in turn engaged by hook bolts. Screen area is lost when apertures coincide with the longitudinals of the supporting frame, and this should be avoided.

The section of mat directly below the point where material is fed on to the screen is subjected to particularly heavy wear, and this is often plated over. The use of a perforated plate instead of a mat in this position is worth considering.

Perforated plates—The holes in these screening surfaces may be either punched, drilled, or flame cut, and in shape may be either circular, square, or rectangular, sometimes with rounded corners. The circular opening gives the most exact sizing, but the proportion of open area is correspondingly reduced. Perforated plates suffer from the disadvantage of having a smaller proportion of open area than any of the types previously described. Closer spacing of the holes would demand a thicker plate with a consequently greater tendency to blind. The main advantage of perforated plates is that they can be subjected to more wear and heavier usage than rod decks or mats before needing replacement. Perforated plates are not tensioned, and generally are not arched. They present a smooth surface to the material causing it to slide rather than tumble along. This helps to prevent the production of fines, but less efficient screening will result. An idea which has been tried when handling abrasive materials such as sinter is to make transverse grooves in the plate. These grooves retain some of the fines, forming a bed which should reduce wear on the metal beneath.

SITE PROBLEMS AFFECTING SCREEN DESIGN AND SUBSEQUENT PERFORMANCE

Lack of Space

Sometimes only a limited space is available for the screen. Lack of headroom makes it difficult to fit the correct feed and discharge arrangements, and may limit the angle of inclination. Lack of space in any other direction may also adversely affect the feed and discharge arrangements, and will restrict the screen length. To save space double- and treble-deck screens

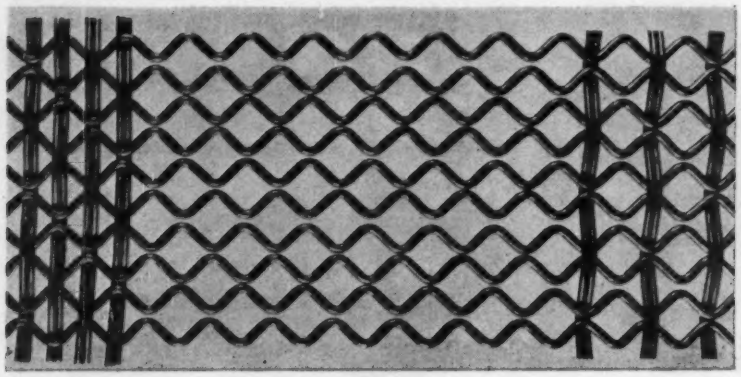


Fig. 16—'Serpentl' mat

are often used, but the best possible screening cannot be expected from this arrangement for a number of reasons. The intensity of vibration will be the same for all decks, and this means that particles of material on one deck will be agitated too much and on another too little. Since lower decks of the screen rely on throughput from those above for their feed, the effective length of the decks is progressively reduced. This latter difficulty can be overcome by the use of deflector plates, but greater headroom will be necessary and the material must be reasonably dry. An additional disadvantage, particularly with treble-deck screens, is that mat changing is made more difficult. Coupled with lack of space often go cramped and dark conditions, where dirt accumulates and maintenance becomes irksome.

Overloading

It may be necessary to increase the tonnage of material passing over a screen owing to expansions in other sections of the plant. Overloading will result in loss of screening efficiency. Screening plant in excess of existing requirements should therefore be installed, if this possibility is foreseen. Although a screen may be designed to handle a certain tonnage of material per hour, in practice it will often be required to handle a much higher throughput for short periods alternated with periods of light running. The overall throughput may be in accordance with the design specification, but the screen will nevertheless have been effectively overloaded. The solution is either to install a larger screen or to provide surge bunkers and even out the loading. This trouble is particularly likely to occur when material enters the plant via a wagon tippler.

If by chance material containing a high proportion of near-size particles, or even of one size range, is received, the screen may be effectively overloaded for reasons previously stated. This problem will occur particularly at works using imported ores, the properties of which vary widely.

Screening can be done more efficiently if the particular sizing is done in two stages. As much of the undersize or oversize material as possible should be removed first. In this way the load on the screen giving close particle sizing is greatly reduced.

Variety of Materials

The screens may have to handle materials with widely varying properties, as discussed previously. This applies particularly to works receiving both home and imported ores. If the same screens handle both types of ore, the intensity of vibrations, angle of inclination, and direction of throw must be arranged to give reasonable results for the worst conditions. This means that the screens will be operating at less than their best efficiency on the dry ore, which may be in the greater proportion. It is recommended that home and imported ores should have separate screens. An alternative would be to design a screen in which the variables can be altered quite easily. This is discussed later.

Production of Fines

Some aspects of this problem have already been discussed: it should be added that since particles of material rubbing together produce fines, final screening should take place after and not before bedding or stocking. In modern plants coke usually has the breeze screened out immediately before being fed into skips for the blast furnace.

SCREENING PROBLEMS

Assuming the screen has been properly designed to give efficient sizing, the following additional problems have to be solved.

Feed Arrangements

The feed arrangements to the screen must be right, otherwise the material may bound down the screen, possibly all on one side, and the effective screen area will be reduced. This may also cause the screening surface to wear quickly and unevenly, and friable material to break up. Material should be delivered to the screen evenly across its width, with as little drop and at as low a velocity as possible. Screens are usually fed by belt conveyors. It follows that these should themselves be evenly loaded across their width. The arrangement of conveyors feeding one another at right angles before the screens is to be avoided. Bifurcated chutes feeding the screens also tend to be unsatisfactory.

In modern screening installations a specially wide, nearly flat, conveyor belt, which can therefore be run at low speed, is sometimes provided to feed material on to the screen. If a conveyor running at a normal speed is used, this should feed on to a baffle plate in a feed hopper and thence to the screen. A back feed

is an advantage from the viewpoint of screening efficiency, but it should avoid throwing material over the back of the screen, especially when the direction of throw is also backwards. The drop from a baffle plate or back-feed chute must be sufficient to clear the largest lump. The feed arrangement from a belt conveyor to a coke screen which gives reasonable satisfaction at one works consists of a long chute at a fairly shallow angle. A big drop on to the screening surface or on to an intermediate baffle plate and the consequent breakage of material is thereby avoided.

With reasonably dry materials the ideal feed arrangement is obtained with a vibrating feeder, although the cost, approaching that of the screen itself, may not be considered justifiable. The electromagnetic type is more common, but a mechanical vibrating feeder might also be used.

When reducing the distance through which material drops on to the screens, care must be taken to ensure that the angle of inclination of the screen deck can still be varied over the full range, and that mat changing is not made more difficult.

When very sticky materials are handled, baffle plates, feed hoppers, etc. are liable to get blocked. The only answer may be a perforated plate at the top of the screen to take the direct impact of falling lumps, and sufficient screen length, if necessary by screens in cascade, to give the required efficiency.

Blinding

The screening surface may blind up either because of near-size lumps jamming in the apertures, or owing to a build-up of sticky material. In the majority of screening plants this is the greatest problem encountered, and it will be dealt with in detail later.

Mechanical Problems

Vibrations transmitted to the supporting structure—The method of reducing these vibrations will depend on the type of screen. If it is activated by an out-of-balance mechanism, then flexible mountings must be used. With other types, balancing arrangements can often be provided as well. Blinding causes the screen to become unbalanced and for this reason is additionally troublesome. Conveyor-belt galleries must not be supported by the framework which supports the screen, otherwise some form of fatigue failure may result. This matters particularly when a number of screens running at close frequencies are in the same building. Under these conditions a large-amplitude vibration will occasionally occur and shake the structure, which should, therefore, be sufficiently rigid.

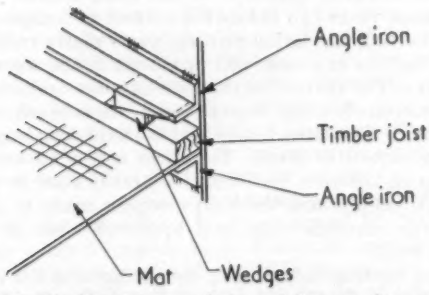


Fig. 17—Method of securing mat by wooden wedges

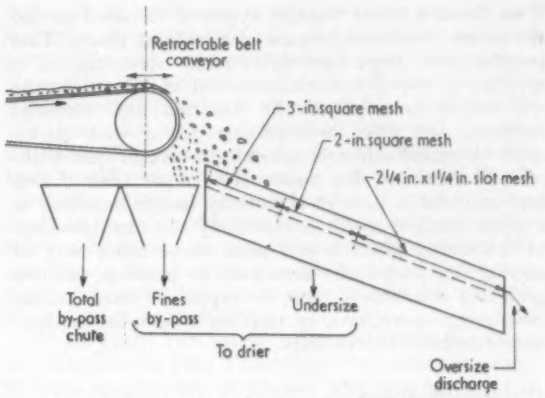


Fig. 18—Retractable conveyor feed to screen

Chafing, loosening, and fatigue of parts—Such troubles naturally occur because of vibration. They will be peculiar to the design and make of screen, and cannot, therefore, be considered further in this paper.

Changing screening surface—The importance of being able to change the screening surface quickly has already been mentioned. One method of keeping a mat or punched plate in position which permits rapid changing is by means of wooden wedges, as shown in Fig. 17. It is suitable only when tensioning is not required.

METHODS OF PREVENTING BLINDING

There are two approaches to this problem. Either an attempt can be made to prepare the material in some way to reduce the stickiness, or the material can be accepted as it is and the screen operated so that blinding is less likely to occur. It should be stated at the outset that with the possible exception of one or two expensive methods the final answer to this problem has not yet been found, and so arrangements for by-passing the screens are essential.

Preparation of Material

Blinding due to stickiness can most effectively be prevented by drying the material. The moisture content of a home ore can be reduced from about 20% to 10% in a suitable drier. This process, however, is expensive and can be justified only in extreme cases, as for example, when the material is received wet and sticky during all seasons of the year. At one works the cost of drying ore in a Buell drier is about 4*s*/ton, which includes 1*s* fuel costs. One consequence of drying is that fines tend to ball together and form small hard lumps. While some of these break up again before screening, others are crushed to fines on the way to the blast-furnace. Even when driers are installed, screening of wet, sticky ore is not entirely eliminated. The material has to be screened, as received, at about 1½–3 in. to remove the larger lumps, since it is generally considered practicable to dry only the middles and fines.

Advantages are obtained from the viewpoint of the

blast-furnace if the various types of ore used at the works are blended by means of a bedding plant. This process also helps the subsequent screening in a number of ways. A certain amount of natural drying will occur because of the aeration the material receives, and drier ores getting mixed with sticky ores. In addition, it is possible to mix in quantities of mill scale and flue dust. Minute particles of this fine material adhere to the sticky lumps resulting in a gritty surface which is less likely to cause blinding. If a bedding plant is not used, some other way of mixing dry and sticky ores may be possible, such as grabbing alternately from stockpiles of each during reclaiming operations, or tippling wagon-loads alternately before the crushers.

Preliminary Sizing

With a sticky ore the smaller particles contain a greater proportion of moisture in relation to their size than the large lumps. The latter, although wet on the surface, will give a somewhat drier product when crushed.

This fact enables an interesting approach to the screening problem to be made at a certain ironworks. A rough separation of the 'natural' (and therefore wettest) smalls and fines is made over a drop-bar feeder and roll grizzly screens before the primary crusher. The material removed in this way, instead of rejoining the crushed product as normally, is screened separately. The screening of the crushed material is thus made easier at the expense of the other. To compensate for this, special arrangements have been made for screening the natural smalls. A screen of the positive eccentric drive vibrating type is used, fitted with a woven wire mat having 3-in. square apertures on the quarter nearest the feed end, 2-in. square apertures on the next quarter, and 2¼ in. × 1¼ in. apertures on the remainder. The conveyor belt feeding the screen is retractable and can feed material in a variety of ways, as follows (*see* Fig. 18).

(i) By suitably retracting the conveyor the material can be fed on to either the small-, medium-, or large-apertured mats, depending on whether it is dry or wet.

(ii) The conveyor can be retracted further to a position just short of the screen. The natural size segregation of the particles of material as they are discharged over the head drum will cause the larger lumps to drop on to the screen and the fines to fall short into a chute. This leads them to rejoin the undersize product from the screen.

(iii) The screen can be by-passed completely if the material is very sticky or consists entirely of fines so that sizing is unnecessary.

Screen and Screening-surface Design

Blinding, especially that caused by the jamming of near-size particles, could be avoided if the screen were given a sufficiently high intensity of vibration. However, this might make stratification impossible and poor efficiency would result.

The vibrating screen driven by a positive eccentric is generally regarded as the most suitable for handling materials which blind easily, since it has a vigorous screening action. Vibrations due to out-of-balance masses become damped when the screening surface is blinded or overloaded. Screens having high-frequency vibrations at small amplitude are regarded as suitable only for fine sizing.

The 'impact' type of screen (Figs. 8 and 9) is not much used in ore and coke preparation plants and so its performance with sticky materials is difficult to estimate. One cause of trouble may be that the edges of the screening surface remote from the source of vibration become 'dead spots' at which blinding can easily start and later spread to the whole surface. When observed sizing coal, there was no jamming of apertures by near-sized lumps.

The simple expedient of substituting a slightly larger aperture size or a slotted (instead of square) mesh will often entirely prevent blinding.

Vitreous-enamelled mats have been tried in the U.S.A. They are said to be successful when breeze has to be screened at $\frac{3}{16}$ in.[6] Presumably the advantage lies in their hard, smooth surface which inhibits abrasion and corrosion.

Blinding of mats can sometimes be prevented by imparting secondary vibrations. One example is the 'Sta-Kleen' feature incorporated in some Allis-Chalmers screens. A retaining deck is located underneath the screening surface. It is divided into compartments containing rubber balls. These balls bounce while the screen is moving and help to dislodge jammed or ahered particles. It is doubtful whether this arrangement would be successful when the stickiest ores are being handled, but might well be of great benefit with coke. Another example is the rubber-stranded mat. The rubber strands, which form slotted apertures, themselves vibrate with the screen and shake near-size particles free. The mat is intended for screening breeze at $\frac{1}{8}$ in. It is expensive, and no information is available regarding life and performance.

Heating

When all other methods fail, screen heating is resorted to. It is applied only to woven wire or welded rod mats. The principle involved is that the surface tension of the water surrounding a particle is reduced on coming into contact with a hot mat, and the tendency to stick is thereby reduced. It must be remembered that heating in itself does not aid screening and a really sticky bed of material may merely slide *en masse* over a heated surface. In addition, a heated screen deck may cause fines to ball together more easily.

Two forms of heating are available, electric and coke-oven gas. Electric heating is out of favour in the iron and steel industry. It was unsuccessful when tried some years ago before the correct technique had been evolved, insulation proving particularly troublesome, and, in any case, gas produced in the works is cheaper. The reverse is the case in other industries, where electric heating is preferred. This is much more convenient, free from fumes and the explosion hazard, and less expensive to run. The initial cost of an electric heating installation, including the transformer to give a 4–6-V supply and the heavy copper leads to take the large currents may well approach that of the screen itself.

A gas heating installation, consisting of a few rows of burners under the screen deck, is simple and robust.

Flames from the jets must not come into contact with the mats, and this can be prevented by shrouding. The figure usually quoted with electric heating for the mat temperature required is 150° F (unloaded) and presumably the same will apply with gas.

As a rough guide electrical heating is more suitable for fine sizing applications and gas for coarse sizing where mats made of rods or wires with a large cross-sectional area are involved. These rods have a low resistance and would take excessively large currents if electrical heating were used. Heating by either means can also be applied to coke screens, but it will not be of any help if blinding is caused through jamming.

Other Methods

(i) Wet screening is an obvious and logical method of handling sticky materials, and would also solve the problem of adhered fines. Although probably effective the subsequent problem of recovering iron-bearing materials from the tailings would be difficult and expensive.[7] Water sprays might help in screening coke at $\frac{1}{8}$ in. where the dewatering problem would not be so difficult.

(ii) A mechanical method of 'carpet beating' the mat is another obvious solution. Greatly increased mat wear would result, and the effect might be only to delay rather than prevent blinding.

(iii) Cascade roll screens have been tried for fine ores at $\frac{3}{8}$ in. The difficulty was found to be that slabby material went through the apertures when the ore was dry.

(iv) Since there is little stratification of a sticky ore, it helps greatly if the feed can be in as thin a bed as possible. In other words, capacity must be reduced.

(v) When material is liable to blind there is no advantage in scalping off the large lumps first and putting only the near-sized lumps over the screen. It is better to arrange two screens in cascade, both fitted with the smaller size mesh. The large lumps tumbling over the mats will help to keep the apertures clean.

(vi) Sizing by means other than screening has been hinted at previously, and pneumatic methods are a possibility, but this subject is outside the scope of the report.

CONCLUSIONS

(1) To obtain efficient and reliable screening, careful attention to detail is necessary. In most ore and coke preparation plants some improvements could be made on the lines indicated in this paper.

(2) Many of the types and makes of screen and screening surface now available, some only recently introduced, are rarely used by the iron and steel industry in this country. Some, such as the resonance screen to size coke at $\frac{1}{8}$ in. are worth considering. A new screening-surface design which has interesting possibilities is the rubber-stranded mat.

(3) There appears to be a number of different types and makes of screen doing each of the sizing jobs in an ore and coke preparation plant with at least a reasonable degree of satisfaction. Since the requirements of each application differ somewhat, and in view of the lack of precise information, a firm conclusion regarding the best type of screen in any set of circumstances cannot be given at this stage. A general indication is given in the tables.

(4) The only precise performance figures available for screens appear to be those given by Taggart.[1] These cover a limited range of screens and materials. They do not show the effect of altering variables such as the speed, direction, and amplitude of vibration, the angle of inclination of the screening surface, and the type of mat employed. An extensive series of tests is the only way of obtaining such information. Since the more urgent problem is efficient screening in the smaller size ranges of material (i.e. ore at about $\frac{3}{8}$ in. and coke at $\frac{1}{8}$ in.) laboratory tests with a model screen would probably be of value, but full-size works tests would also be necessary.

(5) The above information, when obtained, is unlikely to be put to the best practical advantage unless means of altering the screening variables are readily available. An attempt should be made to develop a screen in which this can be done simply, for instance, by operating hand levers.

(6) Normally two stages of screening are employed for sizing ore to $\frac{3}{8}$ in. There might be some advantage if three stages were employed, and this has already been suggested by Cowan.[7] Tests giving a size analysis of the product from the secondary crusher would help to show whether this is necessary, and in what size ranges the screening should be made.

The natural segregation of fines and lumps as material discharges over the end of a conveyor is worth investigating further. Laboratory tests would show whether a worthwhile segregation can in fact be made, and what belt speed, drop of material, etc. should be employed to obtain the best results.

Acknowledgments

The authors would like to take this opportunity of expressing their thanks to the following firms for the assistance and information received: Appleby-Frodingham Steel Co., Colvilles Ltd., Dorman Long (Steel) Ltd., Guest Keen Iron and Steel Co., Ltd., The Sheepbridge Co., Ltd., South Durham Steel and Iron Co., Ltd., The Steel Company of Wales Ltd., Stewarts and Lloyds, Ltd., Workington Iron and Steel Co., G. J. Palmer and Sons Ltd., Samuel Williams and Sons Ltd., South Eastern Gas Board, Allis-Chalmers Great Britain Ltd., Robert Cort and Son Ltd., Denver Equipment Co., Ltd., D.M.M. (Machinery) Ltd., The General Electric Co., Ltd., Hein, Lehmann and Co., Industrial Belt and Screen Co. Ltd., International Combustion Products Ltd., W. J. Jenkins and Co., Ltd., Lockers (Engineers) Ltd., Moxey Ltd., Niagara Screens (Great Britain) Ltd., Nordberg Manufacturing Co., Owl Engineering Supplies Ltd., Pegson Ltd., West's (Manchester) Ltd., Woden Transformer Co., Ltd., Mr. John P. Barlow (Representative in Great Britain for Rheinische Werkzeug-U Metallwarenfabrik GmbH).

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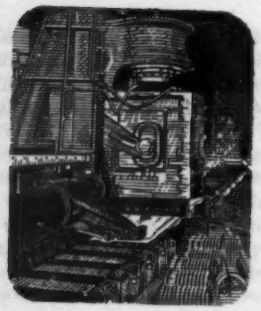


IRON AND STEELWORKS ENGINEERING

The Iron and Steel Engineers Group

Report of the 36th Engineers Group Meeting

The THIRTY-SIXTH MEETING OF THE IRON AND STEEL ENGINEERS GROUP of The Iron and Steel Institute was held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, on Wednesday and Thursday, 16th and 17th April, 1958.

The Chair was occupied by Mr. W. M. LAUKE, Chairman of the Group. Discussions at two of the sessions were published in the August, 1958 issue of the *Journal* (vol. 189, pp. 344–356). Discussion at the third is given below.

DISCUSSION ON ELECTRICAL MAINTENANCE IN IRON AND STEELWORKS

This was a general discussion held on the afternoon of the first day of the meeting.

Mr. **J. T. Mills** (Richard Thomas and Baldwins Ltd., Ebbw Vale), in opening the discussion said: When I was asked by the Committee to open this afternoon's discussion I understood that the idea was not to concentrate too much on methods of maintenance but to give an opportunity for the much maligned but necessary maintenance section of the steelworks team to air some of its grievances.

Of course, maintenance is only a service and production with quality is the thing that really counts. Thus, initial efforts are towards working the equipment up to its designed capacity.

When we come to the choice of electrical equipment, I think that no system of maintenance, however good, can exceed the standard set by the initial installation and component parts of the equipment supplied. There is, therefore, little wonder at our annoyance if we are obliged, on account of delivery difficulties, to accept certain items and designs which we know from practical experience to be unsuited to a steelworks. One of the reasons for the continued inclusion of such items in initial designs is that the manufacturer does not always seem to realize that the job originally commissioned may be radically changed after 2–3 years' operation. In many cases the manufacturer does not take full advantage of all the information which I believe is easily available to him on site. He must send out and get this information as so many do not have either the time or the staff to keep them fully informed. The ideal is to send design engineers to see for themselves.

Should these suggested investigations be carried out, one could imagine having the opportunity of reading the report that would be submitted to their principals. It would probably mention that:

(*a*) Steelworks by their nature are dirty, and there are fumes and dirt of all types some of which elude the most efficient ventilating system.

(*b*) The operator in a steelworks is not normally trained in delicate handling; therefore, instead of dainty controllers, masters, push buttons, etc., robust units should be made.

(*c*) The question of access should receive more consideration, particularly in allowing room and the facilities for making off cables to switchgear, contactor panels, desks, and other control equipment.

(*d*) As large armature changes in a steelworks require so much time why not make bolted connections across the split standard on all machines?

(*e*) There are also still a fair number of problems to solve with regard to commutation and brush grade.

(*f*) It is the inclusion of small commercial components such as fractional horse-power machines which causes trouble. At Ebbw Vale, machines under 1 h.p. accounted for 12% out of the total of some 4500 installed; but 24% of all machine failures were in these fractional sizes. Now, the majority have been replaced by more suitable units. Might it not be a good idea to submit robust components as a standard alternative when preparing quotations?

(*g*) In order to limit loss of production it is essential to design compact, easily removable components, with ample fault-location circuits, so that replacements can be carried out quickly and repairs done at leisure, always remembering that static apparatus requires less maintenance and is quicker to replace.

(*h*) The spares stores in a steelworks might contain 3000 bins for machine spares, 1600 for electronic, and 9000 for control gear. This clearly shows the urgent need for manufacturers to get togetheron fur ther standardization.

(*i*) The steelworks electrical engineer is governed by statutory regulations which must be most carefully considered during the initial design. This is easier than being forced to modify when the equipment gets to site. Also, it is essential to consider in detail the effect of failure of any part or component in a scheme.

(*j*) An easily adjustable or self-adjusting magnetic brake, an overwind limit switch that fails to safety, and an explanation as to whether there is any valid reason why mill-type motors are still supplied with taper shafts, are some questions that mechanical engineers are asking.

Mr. **R. C. Stott** (Steel Company of Wales Ltd.): With the high rate of production in modern steel plants, the value of lost production due to breakdowns might easily exceed the cost in labour and material of a preventive maintenance scheme.

A properly executed plant maintenance programme ensures the maximum service from equipment at the lowest cost. Support from the operating department is essential to the success of any scheme. A constructive scheme of maintenance must include good design, far-sighted planning, independent supervision, definite routine, and rigid inspection by conscientious, well trained personnel.

Close co-operation between managers, engineers, and maintenance staff is essential, as also is good housekeeping and the elimination of abuse and consequent damage to equipment. The attitude of the operator, too, is a major factor. The importance of early reporting of pending trouble cannot be over-emphasized; the necessary corrective action may then be taken before more serious damage occurs.

The essential basis of a preventive maintenance scheme is a comprehensive card-index system in which correct details of each item of plant are recorded together with information on site repairs and—this is important—repairs carried out in the repair shops by outside contractors or manufacturers.

Inspection schedules must be set up to suit operating and other conditions, but each section must be treated separately. The inspection sheets based on the inspection schedules are issued by the plant maintenance office through the departmental foreman to the electrician, who at the end of the current period will return these sheets through the same channel, indicating what repairs have been carried out. An analysis is made in the planning office and the section engineer advised or informed of any part not inspected in order that he may make special arrangements to cover it in the coming period. The office can also note recurring faults and pass this information back to the engineer concerned for action. The inspection system should be applied not only to plant but also to equipment including welders, drills, grinders, etc., and the testing of socket outlets for earth continuity.

The maintenance scheme must be backed by a comprehensive repair-shop organization able to deal with all foreseeable faults and a stores organization which makes available without delay replacement parts, such as switches, armatures, bearings, resistors, control parts, etc. The repair shop and the stores may with advantage be operated as one unit and then be closely integrated with the plant maintenance section to ensure control of spares.

Before closing, I should like to put forward three points on which I seek further information: first, the desirability or otherwise of using solid bearings or roller bearings of the American type, thus eliminating the greasing bogey; secondly, the economics of block changing of lamps, differentiating between tungsten, mercury, or sodium units; thirdly, details of a really successful scheme to prevent magnet-cable breakage.

Sir **Henry Clay** (McLellan and Partners Ltd.): Mr. Mills talked about the effect of maintenance on the choice of electrical equipment. We ought to think about how the designer knows the difficulties of maintenance, or if he knows at all. I think this represents a real difficulty. There is a tendency, particularly in the case of the minor things, for the manufacturers never to hear of the difficulties.

On a temper-mill drive we had trouble with a shaft twisting due to wrecks on the mill stopping the motor so suddenly that the back half of it continued to turn round. We had to put in a new shaft. When I was in the United States afterwards I went to the manufacturers and talked to them about it, but they said that they had never heard of the trouble, that it must be caused by the rolling-mill practice in this country. I went round to a number of steel mills and talked to the actual sevice engineers, and I found that everybody who had this particular type of mill had had this trouble and they had not referred the matter back to the manufacturer but had just put in new shafts. With this in mind, among other things, when we were involved in organizing during the war the maintenance of a large number of ordnance factories, where there were the most elementary ideas of how to keep plant running, we instituted a sort of planned maintenance scheme and also had a fault-reporting arrangement which enabled us to classify troubles on plant and, as far as possible, the cause of the trouble. In fact, we tried to induce the maintenance engineers to classify faults under four headings, which I think were faults in design, faulty material or workmanship, inadequate maintenance, and abuse.

The first two of those headings were very useful in drawing attention to faults in design and manufacture. Also, by correlating all these reports from different factories one began to get an idea of the various types of equipment and particular makes of equipment which were unsatisfactory, and why. That sort of thing should make it possible to bring the faults to the attention of the manufacturer, who, except that he may have sales difficulties, may not know what is wrong.

We found out, I think, why some works constantly got trouble with single phasing and had to put in special devices for that purpose. That was because they tended to put in their back-up fuse protection too close and their fuses were inclined to blow.

Mr. **J. V. Woods** (Laurence, Scott and Electromotors Ltd.): I would agree with Mr. Mills on the subject of designers visiting the site in order to find out at first hand the conditions on the site. That is very important, and it bears dividends in the end. On the other hand, the user must make available all possible information. For his part, that is not always easy because sometimes he does not know in his own mind how the equipment will ultimately operate, though he may have a fair idea. I think most steelworks people come out in the open and tell you everything possible; but invariably the manufacturer finds all sorts of things missing, usually when it is too late. He then does his utmost to make amends and to make the equipment fulfil the later requirements, but, of course, he cannot achieve the impossible.

The designer will visit the site and pick up as much information as possible, but there again, he has his limitations, and he then turns the equipment over to draughtsmen, and those draughtsmen themselves must have a certain amount of experience. The electrical manufacturer, of course, has to manufacture a very wide variety of equipment for all sorts of trades and purposes. So his draughtsmen must be able to accommodate themselves to all sorts of different requirements. A classic example is the trouble you get when stripping down a machine and find that you cannot get the spanner on a certain part. The ideal way would be to have the draughtsman trained specifically for the type of equipment on which he is engaged. That is, of course, not always possible.

But the manufacturer can help in a number of ways. He can provide comprehensive maintenance instructions giving every possible detail of the equipment. That is, of course, important in the case of a breakdown in the middle of the night when it is not possible to telephone the manufacturer.

Reference has been made to brush gear, and the problem of getting at the brushes at the bottom of commutators. That point is worth the attention of all electrical manufacturers. In some cases it is possible to overcome that difficulty by slackening off the brush and rocker and moving it round, but it does mean re-locating, and that can only be done if there is a dowel-pin locating the brush rocker.

Mr. **H. Demaine** (Park Gate Iron and Steel Co.): I do not know of any organization which batch-changes tungsten filament lamps except perhaps over one special machine or piece of plant where it would be difficult to reach the lamps under normal operating conditions. I do not know anyone who does batch-changing of tungsten lighting except perhaps for some special application of that nature.

With regard to discharge lighting, a case could be made out for batch-changing in certain circumstances because the intensity of light falls off after a reasonable life. The age at which the light falls off is known, and by applying one's own economic considerations in relation to light required and light available one can determine when the lamps may or may not have to be changed.

Perhaps a more important point is cleaning of the lamps rather than changing the bulbs. At our works we operate a comprehensive lamp-cleaning programme. Every lamp in the works is cleaned at a fixed interval which varies from three weeks in the dirtiest situations to 12 weeks in the cleaner places, the majority falling within the range of 6–8 weeks. Every lighting fitting has a glass visor fitted to it, and the lamp cleaning is done by electrical contractors, one of the men in charge of the team being an electrician. The men are paid a fixed base rate plus an incentive bonus for cleaning. They clean inside the fittings and outside. We have vitreous enamel fittings 18 years old, and their surface condition is hardly distinguishable from the condition of brand new ones.

It is very difficult to stop magnet cables breaking because it is usually caused by carelessness on the part of the driver. One cable manufacturer made some special magnet cable for us with strengthened cores and sheathed with polychlorocrin. That is the material that has given us the most satisfactory service.

On one or two applications we have converted the spring drum to a chain drive with spring loading, the spring being anchored much as it would be if it were a spring-driven drum. The chain takes the bulk of the travel and the spring takes the balance. That has helped considerably on scrap-handling cranes.

With regard to safety I should like to say a word about the use of low voltages particularly in steelworks and particularly at 50 V. Many years ago I tried to get portable tool manufacturers to supply 50-V tools to our organization, but I was unsuccessful. Eventually a well known firm of tool makers made 50-V tools for British Railways and we have been able to use our 300-W fittings at 50V. In situations where they are infrequently used we use portable transformers of 3-kVA capacity in wooden cases in the furnace department, and where they are frequently used we have a permanent installation of low voltage for the job. We have never had an accident as a result of the use of this equipment.

With machines a little more awkward to handle on low voltage—welding machines, etc.,—we have used the 415-V system with pliable armoured trailing cables with a monitor earth system. It has current passing down the earth wire and returning up the armoured wire, probably 12 V being used. We have made a standard unit. Where any portable tool or apparatus of 415 V is required, we use the circulating current protection for it. We feel that we have obtained a great degree of safety as a result.

With regard to control gear, manufacturing standards seem to vary. One manufacturer making excellent gear a number of years ago changed from stainless-steel interlock and phosphor-bronze strip to silver-plated contacts and we had no alternative but to use the new ones. Fortunately, the manufacturers now make the equipment with the older type of interlock bar and phosphor-bronze strip.

A final point is the reconditioning of equipment in the maintenance shop and testing it when completed. Every motor, generator, or piece of control gear is passed through a testing bed, on which we carry out brake-drum or back-to-back tests. No-load tests are applied and for series machines we can excite the field separately. We find an enormous number of trivial faults, such as brush gear or bearings needing adjustment and inter-poles reversing, which would otherwise not be discovered until the equipment went into service.

One motor a day is passed through this department. Nearly every machine that goes through has some trivial thing wrong which is discovered on the test bench and put right.

Mr. **D. R. M. Nisbett** (Appleby-Frodingham Steel Company): We are the people who have to use the plant which the manufacturer designs for us, and it seems to me that, rather than have the manufacturer coming along to us, we ought to tell the manufacturer what we want.

A lot of the requirements that we shall demand in respect of various types of equipment are obviously dependent on site requirements. On the one hand we wish to cater for various requirements, personal whims almost, and yet on the other hand we are calling out for standardization and it is difficult to draw a line.

Some questions have been raised about lamp changing. Some time ago I instituted the bulk changing of lamps in one of our melting shops. There were about 250 fittings in the melting shop, a combined installation of tungsten and mercury-vapour lamps. Within six months we had gone back to our old system.

The lives of mercury-vapour lamps are 1000 h and 1050 h respectively on 110 V in our works. There was a considerable falling-off in light owing to the short lives of the lamps but we also felt that the system we employed was at fault.

I think that one of the more important aspects of the lighting question is that of lamp cleaning. In the case of our experiment, I made calculations for two installations. I compared a scheme with an estimated depreciation of about 50% and comparatively little lamp cleaning, with an installation designed for an 80% depreciation with an accompanying lamp-cleaning schedule. I found that lamp cleaning saved £3500 a year in power alone, because on account of the dirt, the electricity was only warming up the fittings.

Someone has made reference to low-voltage tools. We have a compromise arrangement at our works, where we use 110 V. We have a double-wound transformer and centre-tap the secondary winding so that we have 55 V to earth and have had no difficulty in getting 110-V tools. Most manufacturers will supply them, but they usually take longer in delivery. The system has the advantage of using less copper wire than a 50-V system.

Mr. **W. Spence** (British Thomson-Houston Co. Ltd.): Mr. Mills pointed out that with complicated equipment what is required is compact, easily removable components which can be serviced in the maintenance shop. There is also the view that plugging units are undesirable, that plugs and sockets are not reliable and that fault tracing is not sufficient because the fault occurs when the equipment is fitted out on the plant. That is true. What is the alternative? Panels can be so openly laid that checking is possible while observing the operation in the plant with the panels *in situ*. Both systems have their merits.

It is most essential that on these large plants with complicated electrical equipment the manufacturers should supply detailed operating instructions but I would also make a plea to the users to see that these books are read by the people for whom they are intended. All too frequently we get telephone calls at awkward times and arrive at the site to find that there would have been no need for a visit had the instruction book been properly read.

Mr. **Freeman** (McLellan and Partners): Ventilating-plant maintenance in large electrical-drive motor rooms in steelworks where 1000 or 2000 kW has to be removed is difficult. The plant is designed for full load on a hot day, and the consequence is that they run for months without anybody realizing that they may be dropping in efficiency. In most works they are often the last items of equipment to get attention from the maintenance staff. Maintenance is complicated because half the plant is mechanical, with air washers, filter plant, and pipe-work, and access is possible only with an electrical key.

What is the ideal design of ventilating plant for these large motor rooms? Is it a type of filter which satisfies maintenance requirements although not the most efficient or economic from the point of view of the designer? Are there any special problems in maintaining ventilating plant which could be solved by due attention in the design stage?

Mr. **J. Poole** (Steel Company of Wales Ltd.): Originally we had two systems, one in the slabbing mill and the other in the continuous strip mill. In the former the air was introduced at one side of the motor room and taken out at the other, returning to large air-to-water heat exchangers at the end of the slabbing-mill annexe. In the strip-mill system the air blew in from both sides of the room and went out through the roof, taking the heat with it.

We had difficulty in maintaining the various auxiliary systems—the water pipes, the air-to-water heat exchangers, the water coolers which cool the water after it passes through the exchangers, and so on—and we originally had to include within our electrical department some mechanical people who worked constantly on this equipment.

At the present moment, the slabbing-mill system which was not functioning very well is being changed to make it similar to the one in the strip mill, so that eventually both systems will be straight-through. We are also increasing the capacity of the water-cooling units which are outside and deteriorate rather rapidly. The mechanical staff associated with the particular motor rooms do a regular inspection and examination system. They check the pumps and pipes of the coolers for leaks and they examine the water coolers outside because there we have various grillages and small things which deteriorate rapidly.

We had originally electrostatic filters in our slabbing-mill system capable of cleaning the small amount of make-up air required for losses in the original system. We are replacing them with the fully automatic, oil-wetted viscous filters and increasing the size of our filter capacity accordingly to change the system from recirculating to straight-through.

The strip-mill system, which has not given so much trouble, is being enlarged a little and we shall change the original oil-wetted hand-operate dfilters for fully automatic ones.

Mr. **Mills** (replying to the discussion): Magnet-cable breakage depends on how considerate your operators are. The real cure is to use mechanical tongs.

I agree that 50 V is the answer if you have the opportunity, although it might be as well to have double-wound transformers with a centre tapping, giving 25-V lighting. That is a great deal better in some difficult locations.

If conversions are necessary and all existing portable tools are wound 250 V, 110 V is what one should go for, because 250-V tools can be re-wound cheaply to 110 V.

The question of what to do with larger equipment if the voltage cannot be lowered is difficult and very controversial. Earth monitoring has been suggested. It introduces two small relays in the safety circuit, and it is not always possible to earth the earth conductor and cable screening solidly. Therefore, I submit that a double earth with an armoured cable and core balance is best for real safety on large transportable as against portable equipment.

The use of a test bed is complementary to planned maintenance. Machines must be tested properly before putting them back as available spares ready for the next routine change.

I was surprised to find that Mr. Poole was considering going back to the oil-washed type of filter. We have had trouble with them all the time and we have changed now to the fully circulating system and take our make-up through the pad-type filters. I prefer a number of smaller fans to big fans because the system is more flexible.

Mr. **R. A. Lake** (Richard Thomas and Baldwins Ltd., Ebbw Vale): I disagree that the key to planned maintenance is a card index system. I suppose there are about 60 persons here, and I imagine they all have different ideas about what really constitutes the key to the planned maintenance job. I suggest that the solution is really only the separation of inspection from the carrying out of the work; once that is done planned maintenance has been initiated.

Of electrical maintenance in a steelworks, 80% is mechanical. All the inspection systems that are used for the mechanical side can be used on the mechanical parts of the electrical plant. Advanced electrical engineers might consider it desirable to carry out shearing-bridge tests to detect deterioration in the resistance which might cause future trouble, but I should say that the setting up of the apparatus is hardly worth while.

Sir Henry Clay spoke about a piece of apparatus giving satisfaction in one works and great dissatisfaction in another. This is in accordance with my own experience.

Mr. **P. E. Peck** (British Thomson-Houston Ltd.): Some people recommend an oil-wetted viscous type filter as being a good all-round job, not too difficult to maintain, not too expensive, and not too elaborate. The electrical apparatus becomes saturated with oil, dust sticks to it, the electrical equipment becomes the filter, and circulating systems and electrostatic filters are required.

Automatically cleaned types of filters are more or less fixed units but of the moving cordon type, it being possible to move the units round either continuously or at regular intervals. The filter is in the form of a cordon of short wiry parts which form an intermeshed net of ferrules or coiled-up metal, such as turnings and so on.

Regarding replaceable items, mention was made by one speaker of the fact that some people will not have plug contacts at any price. We are endeavouring in our

control gear to compromise in this respect by having unit contactors removable from their panels or frameworks just by disconnecting various interlocking leads and their main connections. They can then be serviced or replaced. That overcomes the difficulty about plug contacts, and provides an easy servicing scheme for replacement.

With totally enclosed multi-motor control units requiring a fairly robust type of plugging arrangement, finger-pressure and body-type contacts are being used for making the connections, the control unit being on a tray. Oil circuit-breakers from most manufacturers are largely dependent on plug contacts, and on the whole they appear to be fairly satisfactory.

Mr. **H. S. Brown** (English Electric Co. Ltd.): Electrical manufacturers are very much aware of the problems and are doing their best to tackle them.

Ideas must be interchanged with operating personnel at a fairly low level. It is certain that any complex control gear can be introduced into the works only if the young people there are educated to deal with it. Engineers should be sent to the manufacturer's works to be trained in the design, production, and manufacture of equipment.

Most countries abroad are now willing to send their engineers to be trained in steelworks manufacturing organizations in this country and as our export market expands this will become more important.

I think oil filters in the early stages were condemned because they tended to be designed to operate at too high a velocity. The need to keep the oil clean was not realized. Where the filter was to be employed in a very bad situation the need for easy degreasing was not foreseen. The result was that if the filters were overloaded they became far too dirty and could not be maintained properly.

There are certain types of units which we may want to interchange fairly quickly and often, but amplifiers and contactors do not require the unit type of construction, and the ordinary bolted connection can be used. I think that both systems will be used in the future.

Mr. **Stott**: I have experienced the hit-and-miss methods of maintenance and have seen the introduction of a planned maintenance system reduce delay times. The basis of the system is a card index of all equipment, and one must make certain that everything is examined, not only the machines causing trouble, but also those liable to break down and cause delays.

Batch changing of 950 tungsten lamps over an eight-week period gave four weeks with no trouble, but gradually over the next four weeks failures increased and became excessive at eight weeks. Operators do not mind whether illumination is high or low provided that it even; this is endorsed by lighting engineers.

Mr. **Nisbett**: At the moment we have a certain amount of plant, and it is all itemized. The plant is divided up into sections in which there are a number of shift electricians. We think that it is desirable to look at each piece of plant every 13 weeks.

We have no major breakdowns that could justify any system which costs any more money. Our delay figures are negligible, 0·5% being electrical. We are inclined to leave bearings alone rather than grease them. Our experience is that if semi-skilled or unskilled men are allowed to grease bearings, bearing failures immediately follow. It is a question of over-filling. It seems to me that we should use sealed bearings.

Mr. **Mills** (further replying to the discussion): I agree that taper shafts are a nuisance, and that any suggestion that a coupling is easier to fit on a taper shaft can be completely discounted. It has to be just as good a fit as on a parallel shaft.

We are trying, as Mr. Brown suggested, to arrange foreman and chargehand training courses, parts of which are an interchange with manufacturers.

When we come to the question of removable units these should be taken out in reasonable time without having to examine the circuit with the mill stopped, and repaired at leisure in the shop; that is the main purpose of interchangeable units.

Mr. **Lake** : The coupling on the taper shaft to the mill motor should fit tightly. Mr. Mills suggests that we should get back to parallel shafts and couplings. That can only be done if you have in your shops hydraulic presses for pulling them off and putting them on.

Mr. **Brown**: With regard to couplings, I agree except on the question of the hydraulic press. In the case of locomotive traction, the coupling has been so arranged that it can be removed by oil injection. With a slight taper on the shaft immediately it starts to move it becomes loose, whereas with a parallel shaft sticking is possible.

On large mill motors and rolls the oil-injection method has been used to a very great extent and as a manufacturer, I should be interested to hear about its applications in fitting and removing a set of mill motors, which have to be handled by the normal mill maintenance men.

Handbook on Non-destructive Testing

"Memorandum on Non-Destructive Methods for the Examination of Welds," British Welding Research Association booklet T.29/1, price 7*s.* 6*d.*. is the last in a series of three booklets which form the B.W.R.A's handbook of non-destructive testing. The others (T.29/2 "Photographic Aspects of Weld Radiography," price 3*s.* 6*d.*, and T.29/3 "X- and Gamma-Ray Safety Precautions," price 2*s.*) were published in June, 1956, and March, 1957, respectively. T.29/1 replaces an earlier Memorandum, T.29. Its main chapter headings are: radiographic methods, ultrasonic and other acoustical methods, magnetic methods, penetrant methods, gas leak method, the proof test or overload test, and semi-destructive methods. There is a glossary of terms in radiography, an appendix showing the defects in welds revealed by various examinations methods, and another showing their applicability to the different welded joint forms.

B.I.S.F. Booklet

Eric Wigham is the author of the latest in the British Iron and Steel Federation's series *Steel Today*, entitled "The Steel Industry's Labour Record." It is pointed out that the industry's record is unparalleled; apart from the 1926 General Strike, it is more than 40 years since there was a major dispute in the industry involving production workers.

B.S.C.R.A. Annual Report

In the Fifth Annual Report of the British Steel Castings Research Association, reference is made to the fact that there is already a need for extension of the laboratories at East Bank Road, Sheffield, opened only last year. Amongst other researches described, one of interest is the investigation of oxygen injection on basic arc furnaces, which is being studied to assess the effect of variables such as initial carbon level, metalloid content, temperature, injection rate etc.

N E W S

Announcements and News of Science and Industry

THE IRON AND STEEL INSTITUTE

Autumn General Meeting

The Autumn General Meeting of the Institute is to be held at 4 Grosvenor Gardens, London, S.W.1, on Wednesday, **10th December.** After the official business, there will be simultaneous discussions on creep and continuous casting. The detailed programme will be published later in the *Journal*. The General Meeting will be followed on 11th and 12th December by a meeting of the Engineers Group, on vacuum processes in the iron and steel industry.

11th Hatfield Memorial Lecture

The 11th Hatfield Memorial Lecture is being delivered by Dr. N. P. Allen, F.R.S., Superintendent of the Metallurgy Division of the National Physical Laboratory, in London on Tuesday, **9th December**, the evening before the Institute's Autumn General Meeting. The subject, place, and time will be arranged later. Admission is by ticket only; tickets may be obtained free on application to the Secretary.

NEWS OF MEMBERS

Mr. **E. H. Baldwin** has been appointed Blast-furnace Manager at the Clyde Iron Works of Colvilles Ltd.

Mr. **H. Bates** has joined the Research and Development Department of Head, Wrightson and Co., Ltd.

Mr. **J. Beech** graduated at Sheffield University with first-class honours in metallurgy and was awarded the Mappin Medal and Premium; he has since joined the metallurgical research staff of the British Steel Castings Research Association.

Dr. **P. R. Beeley** has resigned his position as foundry manager at Sheepbridge Alloy Castings Ltd., to take up an appointment as Lecturer in the Department of Metallurgy, University of Leeds.

Dr. **U. G. Bhat** is now a Research Fellow at the Mellon Institute, Pittsburgh; he is head of a research group engaged on the development of ultra-high-strength steels.

Sir **Charles Bruce Gardner,** BT., has retired from the Board of John Lysaght Ltd.

Dr. **C. J. Dadswell** has been elected Chairman of the British Steel Founders' Association.

Dr. **W. E. Dennis** is now Assistant General Manager of the Redbourn Section of Richard Thomas and Baldwins Ltd.

Mr. **H. H. Egginton** has left Teddington Refrigeration Controls Ltd., to become Deputy General Manager of British Ropes Ltd., Doncaster Wire Mills.

Mr. **W. H. Everard** has been appointed Secretary of the Electric Steelmakers' Guild.

Mr. **W. S. Hindson** has succeeded Mr. R. J. Barritt as Managing Director of the Indian Steelworks Construction Co., Ltd. (ISCON).

Dr. **R. Hunter** has been elected Vice-Chairman of the Council of the British Steel Castings Research Association.

Mr. **C. H. Kain** has been elected Vice-Chairman of the British Steel Founders' Association.

Lord Riverdale of Sheffield has joined the Board of Newton Chambers and Co., Ltd.

Mr. **C. W. Robinson** has been appointed a Chevalier First Class of the Royal Order of Vasa by H.M. King Gustav VI Adolf of Sweden in recognition of his services to Sweden and Swedish interests.

Dr. **Richard Seligman,** Chairman of the A.P.V. Co., Ltd., did not seek re-election to the Board at the recent meeting; he has taken the position of President.

Mr. **F. H. Treherne-Thomas** is now Director and Manager of Monks Hall and Co., Ltd., Warrington.

Dr. **B. C. Woodfine** has been appointed Chief Metallurgist of the Atomic Energy Division of the General Electric Company Ltd.

Mr. **A. Young** has been appointed Works Manager of the Clyde Iron Works of Colvilles Ltd.

Obituary

Professor Dr. **Carl Axel Fredrick Benedicks** (*elected* 1905; *Carnegie Gold Medallist* 1908; *Honorary Vice-President* 1922; *Bessemer Gold Medallist* 1927), of Stockholm, on 16th July, 1958.

Mr. **Percy Blackburn Henshaw,** ASSOC.MET., F.I.M. (*elected* 1909) of Sheffield, on 24th May, 1958.

Mr. **Bjarne Schieldrop** (*elected* 1930), of Stotfold, Bedfordshire, on 2nd July, 1958.

IRON AND STEEL ENGINEERS GROUP

The Thirty-Seventh Meeting of the Iron and Steel Engineers Group will be held in Chester from **14th to 16th October.** The Meeting will open with a presentation and discussion during the afternoon of 14th October of the following papers (dates refer to publication in the *Journal*):

- "Crane Safety in the Iron and Steel Industry": A report of a Sub-Committee of the Accident Prevention Committee of The British Iron and Steel Federation.
- "Ergonomic aspects of the design of cranes" by R. G. Sell. (Oct., 1958).
- "Some ergonomic investigations into the design of motor controllers" by A. Box and R. G. Sell. (Oct., 1958).
- "Recent developments and devices in engineering psychology" by C. B. Gibbs. (Oct., 1958).
- "Human temperature regulation and the steel industry" by R. F. Hellon. (Oct., 1958).

On Wednesday, 15th October, there will be an all-day visit to the Irlam Works of the Lancashire Steel Manufacturing Co., Ltd., followed by a Dinner in Chester by invitation of the Company.

The morning of Thursday, 16th October, will be devoted to presentation and discussion of the following:

" Structural Design of Steelworks Electric Overhead Cranes " by D. Buchanan and R. G. Tyler. (April, 1958)

" Plain Frame Method of Analysis for Lattice Girders " by R. G. Tyler. (Oct., 1958)

Circular notices about the Meeting will be sent out to all members. Copies of the Crane Safety report will be sent to all those attending.

BRITISH NUCLEAR ENERGY CONFERENCE

Symposium on Nuclear Fuel Cycles

The Institute of Physics is arranging a symposium on nuclear fuel cycles in London on 22nd and 23rd January, 1959. The programme is as follows:

Session 1: (*a*) Long-term reactivity changes
(*b*) Theory of once-through fuel cycles
(*c*) Perturbation due to fuel cycles.

Session 2: Optimization of fuel cycles for nuclear power stations.

Session 3: Fuel-cycle operational problems.

Application forms for tickets are obtainable from the Secretary, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

EDUCATION

Refractories Course

Mr. L. R. Barrett, M.A., B.SC., is delivering a course of lectures on " Refractories: Their Manufacture, Properties, and Applications " at Borough Polytechnic on Fridays at 7 p.m., beginning on 10th October. Application forms for enrolment for the course, which is designed to provide a detailed and up-to-date survey of refractories and the refractories industry, may be obtained from the Secretary, Borough Polytechnic, Borough Road, S.E.1.

Mechanical Engineering Drawing

A new scheme of engineering drawing has been introduced by the City and Guilds of London Institute, and college courses will begin in the new session. It is designed to provide a good background qualification to enable the engineering apprentice to become a draughtsman. The course includes applied mechanics, mathematics and geometry, materials and processes. Full particulars may be obtained from the Director of the Institute, Gresham College, Basinghall Street, London, E.C.2.

Courses at Borough Polytechnic

Borough Polytechnic, Borough Road, London, S.E.1, has organized a course of eight lectures on recent developments in metal finishing, being held on Wednesdays at 7 p.m., starting on 8th October. Other courses offered cover fuel technology, fuel and combustion, engineering, and oil-burning technology.

NEWS OF SCIENCE AND INDUSTRY

Retirement of Dr. Walzel

Professor Dr. Richard G. Walzel retired recently from the chair of ferrous metallurgy at the Montanistische Hochschule, Leoben, Austria, and also from the position of Vice-President and Honorary Director of Verein Eisenhütte Oesterreich. He had been associated with the latter society for 25 years, and at the Annual Meeting on 18th May was elected an Honorary Member. He will continue to serve on the Council of Eisenhütte Oesterreich in an advisory capacity. At the same meeting it was announced that Dr. Walzel had been elected a Foreign Corresponding Member of the Verein deutscher Eisenhüttenleute.

Dr. Walzel has been succeeded by Professor Herbert Trenkler, both as Professor at the Hochschule and as Vice-President and Honorary Director of Eisenhütte Oesterreich. Dr. Trenkler, who is 50, was formerly works manager of the Vereinigte Oesterreichische Eisen- und Stahlwerke A.G. at Linz-Donau.

Chilean Steel Institute

The Instituto Chileno del Acero (ICHA) was formed in December, 1957, on the initiative of a group of Chilean trade associations. Its objects include market research, the study of the productive capacity of the industry, standardization of products, scientific research, and the organization of statistical information and technical assistance services. The address of the Institute is Moneda 973, Of. 728, Santiago, Chile.

National Industrial Safety Week

The slogan for this year's National Industrial Safety Week (29th September—4th October) is " Extra Care Stops Falls." In 1956 falls accounted for 14% of all reported industrial accidents, and so their prevention is a matter of major importance from the point of view of productivity. The Royal Society for the Prevention of Accidents, which has organized the nation-wide campaign, has prepared an imposing range of publicity material, built round a character known as " Humpty Bumpty "; in addition to the usual posters, there are leaflets, booklets, letter stickers, and even drip mats, all reiterating the campaign slogan.

Cold Rolling Plant for Brinsworth

The continuous medium-strip mill of Steel Peech and Tozer at Brinsworth is to be augmented in the next two years by a cold-rolling mill and ancillary equipment, capable of handling up to 2000 tons of cold-reduced strip per week. After pickling, coils of hot-rolled strip will pass through a tandem cold-rolling mill, continuous annealing furnaces, and a skin-pass mill. The new mill will roll carbon-steel strip up to 18 in. wide to thicknesses of 0·10–0·25 in.

Italian Metallurgical Congress

The Eighth Annual Meeting of the Associazione Italiana di Metallurgia is being held in Turin on 21st–24th September. The programme includes technical sessions and works visits, including FIAT at Turin and Olivetti at Ivrea.

Current Practice in Fuel Efficiency

The Fifth Refresher Course for works managers and works and plant engineers organized by the National Industrial Fuel Efficiency Service will be held, as usual, at the Clarendon Laboratory, Oxford, from 22nd to 26th September. Included in the subjects to be covered will be " Coal—The Future Trend in Production," " Oil—Industrial Application," " Use of Small Coal in Industry," " Industrial Use of Gas," " Electricity in Industry," " Boiler Efficiencies," " Steam Utilisation," " Clean Air—Smoke Alarm Equipment," " Instrumentation," and " Thermal Insulation." Fees: Resident Members £12 12*s*. 0*d*.; Non-Resident Members £7 7*s*. 0*d*. The complete programme and further details may be obtained from the Secretary to the Course, Mr. E. S. Watkin, N.I.F.E.S., Ailsa House, 181 King's Road, Reading, Berks.

International Congress on Electro-Heat

Mr. C. R. Wheeler, C.B.E., President of The Iron and Steel Institute, is a member of the Committee of Patronage of the 4th International Congress on Electro-Heat, which is to be held at Stresa, Italy, in May, 1959. Nearly 200 papers have been submitted for the Congress, 20 of them from the U.K.

Bessemer Centenary in Sweden

Sandvikens Jernverks AB celebrated on 18th July the successful conclusion of the experiments which had been carried out 100 years ago by Mr. Göran Fredrick Göransson, the founder of the Company. These established the Bessemer process as a practical commercial process. The yield of usable steel rose to 70% and increased during the next few weeks to over 80%. The experiments are described in the paper by Mr. Per Carlberg published in the *Journal* for July, 1958.

The programme included a visit to Edsken, where the first converter was installed. This no longer exists but the ruins of the small blast-furnace, picturesquely situated in the woods by a little stream which provided power for the blast, have been carefully preserved. There was also a visit to Högbo, where the early steel was forged. The Manor Houses and Estate which formerly belonged to the Göransson and Magnusson families were recently acquired by the city of Sandviken and now form a People's Park. The lower forge has been restored as a museum of old ironmaking processes.

There was a short service at the Högbo Church, where G. F. Göransson used to worship, with a commemorative address by the Rev. G.-G. Smedshammar. (The Church has a wonderful collection of historical portraits.) A wreath was placed on Göransson's grave in the churchyard on behalf of the family by Miss Sigrid Göransson, his granddaughter.

An interesting exhibition had been arranged in the Company's Head Office. Mr. W. Haglund, Managing Director, welcomed the guests and placed a wreath before Mr. Göransson's bust. A wreath was also placed before his statue on the town green by Mr. G. Westerberg, General Manager, on behalf of the Company. Mr. Carlberg, in a lecture, gave an account of the experiments at Edsken and also explained the remains at the sites visited.

In the evening there was a dinner at the Stadshotell, attended by about 120 guests. These included officials of the Company and all available members of the Göransson family and their connections, and also Mr. Evert Wijkander, President, and other representatives of Jernkontoret, which 100 years ago had done so much to ensure the success of the experiments by technical and financial assistance. The Secretary, representing the Institute, read a message from Mr. H. Douglas Bessemer, great-grandson of Sir Henry Bessemer, and presented to the Company a section cut from a rail rolled at the Dowlais Works from material made in an early cast. Unfortunately, Mr. K. F. Göransson, President of the Company and grandson of Consul G. F. Göransson, was prevented by ill-health from attending the celebrations, which he had organized. K. H.-M.

Peaceful Uses of Atomic Energy

Geneva is the venue for the Second International Exhibition of the Peaceful Uses of Atomic Energy, which is being held from 1st to 14th September.

New Beardmore Testing Department

On 27th June Mr. P. M. Thomas, Managing Director of William Beardmore and Co., Ltd., Parkhead Steel Works, Glasgow, opened their new Mechanical Testing Department, the latest stage in a programme of continuing development. This replaces the previous Test House, which was located in an older part of the works.

Housed in a very modern, light and spacious building, the testing equipment, which covers a wide range of machines for mechanical testing, includes various new items, including a Losenhausenwerk Charpy test machine, and two new tensile testing machines, an Avery 100-ton and a Denison 50-ton universal testing machine. An autographic load/extension recorder has been incorporated as an extra in the Denison machine, to permit the production of a complete graph of the tensile tests up to and including the actual point of fracture. Production of test pieces and specimens to the fine accuracy of B.S. Specifications takes place in an extensive machine shop, in which facilities here have been further enlarged by the installation of a Cincinnatti milling machine, a Churchill grinder, a Herbert Smallpiece profiling machine specially modified for this type of work, and two Ormerod shaping machines.

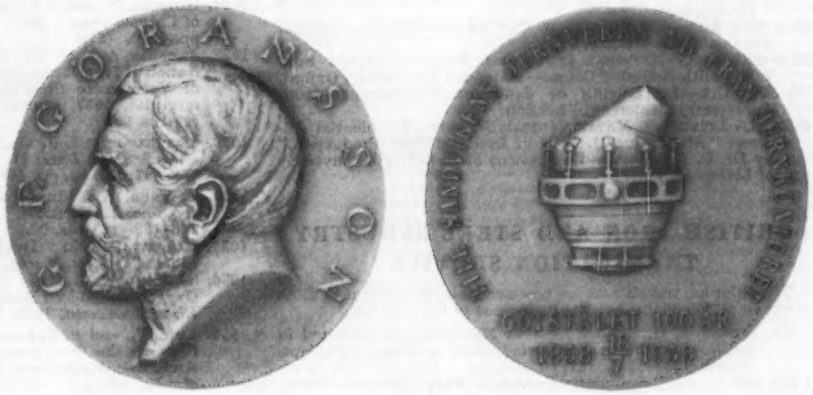
B.W.R.A. Open Day

The British Welding Research Association held its Annual Luncheon and Open Day at Abington Hall, the Association's research station near Cambridge, on 11th June. Despite inclement weather, nearly 500 visitors toured the laboratories and examined the various researches which were in progress.

The guest of honour was Sir Claude D. Gibb, K.B.E., D.SC., F.R.S., one of those initially concerned with the founding of the B.W.R.A., who during his speech at the luncheon spoke of the rapid development of the Association and the increasingly important role it had to play in the industrial life of the nation.

C.R.L. Changes

The name of the Chemical Research Laboratory has



A reproduction of the medal struck by Jernkontoret to commemorate the centenary on 18th July, 1958, of the success of the experiments conducted at Edsken, Sweden in developing the Bessemer process. The medal, struck in gold, was presented to the Sandvik Steel Co., Ltd., and silver medals to Mr. K. A. F. Göransson, grandson of the founder of the Company who conducted the experiments, Mr. Erik Forsberg, former Managing Director, and Mr. Wilhelm Haglund, Managing Director. A replica in bronze was presented to the Secretary who represented the Institute.

been changed; it is now the National Chemical Laboratory. Its function has also been changed; it will now no longer cover the whole range of chemical research. Instead, only a limited field will be dealt with, so that the laboratory's contribution to selected problems of national importance will be greater.

Industrial Publications Received

"This is TI Today" lists the home subsidiary and associate companies of Tube Investments Ltd., and briefly notes their main products.

An attractive booklet entitled "Facts about Albright and Wilson" describes the structure of the Albright and Wilson group of companies and the activities of some of the members of the group.

Information sheet No. M811 from William Jessop and Sons Ltd., deals with the corrosion resistance of titanium.

Metalectric Furnaces Ltd. have produced a leaflet (No. M21a) describing bench-type muffle furnaces.

A "Literature List" detailing the wide range of booklets on production, properties, fabrication, and uses of alloy steels and irons available free from their technical library in London, has been issued by Union Carbide Ltd., Alloys Division.

Two new technical publications come from Sunvic Controls Ltd.: No. 1241 "Recording Control Station" and No. 1251 "Liquid Level Controllers."

The first of the new D.S.I.R. Series, "Notes on Water Pollution," deals with the effect of organic discharges on the level of oxygen in a stream.

DIARY

1st–14th Sept.—2ND INTERNATIONAL EXHIBITION OF THE PEACEFUL USES OF ATOMIC ENERGY—Geneva, Switzerland.

2nd–6th Sept.—AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY (Port Pirie Branch)—Symposium on Sintering—Port Pirie, South Australia.

3rd–10th Sept.—INTERNATIONAL ASSOCIATION FOR CYBERNETICS—2nd International Conference—Namur, Belgium.

3rd–9th Sept.—INTERNATIONAL FEDERATION OF ELECTRON MICROSCOPE SOCIETIES—International Congress—Berlin, Germany.

5th–8th Sept.—ASLIB—Annual Conference—Nottingham.

7th–12th Sept.—AMERICAN CHEMICAL SOCIETY—134th Meeting—Chicago, Ill., U.S.A.

7th–20th Sept.—31ST INTERNATIONAL CONGRESS OF INDUSTRIAL CHEMISTRY—Liège, Belgium.

8th–12th Sept.—BRITISH NATIONAL COMMITTEE FOR NON-DESTRUCTIVE TESTING—Summer School—Manchester College of Science and Technology.

15th–20th Sept.—DEUTSCHE KERAMISCHE GESELLSCHAFT—6th International Ceramic Congress—Wiesbaden, Germany.

20th–23rd Sept.—UNIVERSITY OF LJUBLJANA—Colloquium on Arsenic, Copper, and Other Trace Elements in Ores, Iron, and Steel—Portorose, Yugoslavia.

21st–24th Sept.—ASSOCIAZIONE ITALIANA DI METALLURGIA—8th National Congress—Turin, Italy.

22nd–26th Sept.—INSTITUTE OF METALS—Jubilee Autumn Meeting—Birmingham.

22nd–25th Sept.—INTERNATIONAL GAS UNION—7th International Gas Conference—Rome, Italy.

22nd–26th Sept.—NATIONAL INDUSTRIAL FUEL EFFICIENCY SERVICE—Fifth Refresher Course—Clarendon Laboratory, Oxford.

7th–10th Oct.—INSTITUTION OF STRUCTURAL ENGINEERS—50th Anniversary Conference—London.

9th Oct.—LIVERPOOL METALLURGICAL SOCIETY—Presidential Address: "Alternative Methods of Iron and Steel Production," by Dr. C. Bodsworth—Department of Metallurgy, University of Liverpool, 7 P.M.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on p. 360 of the August, 1958, issue of the *Journal*:

709. VIEREGGE, G.: "Tool Wear in Machining, as Reflected in the Wear/Cutting-speed Curve." *Stahl u. Eisen*, 1957, Sept. 5th. pp. 1233–1244. (£7)

796. BLAIN, P.: "Automatic Control of Strip Thickness during Rolling." *Rev. Gén. Méc.*, 1957, Jan., pp. 13–18; Feb., pp. 63–67. (£6 10*s.* 0*d.*)

801. HEYNERT, G., *et al.*: "The Metallurgy of Ferro-manganese." *Stahl u. Eisen*, 1957, Nov. 28th, pp. 1717–1728. (£6)

813. NIKITSKAYA, V. A., and A. M. KARPUNIN: "Longitudinal Cracks on the Flanges of Railway Rails." *Stal*, 1957, April, pp. 347–351. (£3 10*s.* 0*d.*)

899. LAMPMANN, H.: "The Fully Continuous Medium Strip Mill of Th. Wuppermann G.m.b.H., Leverkusen." *Stahl u. Eisen*, 1958, Feb. 6th, pp. 160–167. (£5)

912. BENESOVSKY, F., and W. HOTOP: "The Effect of Boron on Liquid-phase Formation in Sintered Steel, especially 18Cr–8Ni Types." *Stahl u. Eisen*, 1958, Feb. 6th, pp. 149–152. (£3)

919. GAUTIER, A.: "A Creep Machine under High Vacuum and for Low Stresses." *Rev. Mét.*, 1958, Jan., pp. 9–16. (£3)

929. KALLING, B.: "Improvement of Basic Converter Steel in the Domnarvet Iron and Steelworks." *Stahl u. Eisen*, 1953, Nov. 5th, pp. 1446–1452. (£4 15*s.* 0*d.*)

941. BARBAZANGES, C., and A. RICHARD: "Construction of Electric Arc Furnaces." *L'Aciérie Electrique*, 1957, (Cahiers du Cessid) No. I, Part 1, pp. 1–40. (£10)

947. BRÜGGEMANN, T.: "The Effect of Impurities in the Steel on the Hysteresis Losses of Hot-rolled Transformer Sheets." *Neue Hütte*, 1957, July, pp. 404–409. (£3 15*s.* 0*d.*)

948. FELLCHT, K., and H. KUTSCHER: "The Melting of Transformer Steel." *Neue Hütte*, 1957, Sept., pp. 525–537. (£8)

957. KRAPCHIN, I. P.: "Calculating the Total Cost of Steam Generated in Waste-heat Recovery Installations." *Stal*, 1958, March, pp. 253–256. (£3 15*s.* 0*d.*)

971. BUCH, G.: "Installation and Operation of the Reversing Hot-strip Mill." *Blech*, 1957, Nov., pp. 81–85. (£3)

972. SCHULTEN, H.: "Weighing Machines for Rolling Mills." *Blech*, 1957, Nov., pp. 92–98. (£4 15*s.* 0*d.*)

980. KOTTMEIER, F.: "The Application of Centrifugal Shot Descaling Plants in Bar-drawing Plants." *Stahl u. Eisen*, 1958, March 20th, pp. 358–364. (£4 15*s.* 0*d.*)

985. MOISEEVICH, S. I., and I. N. OZHIGANOV: "Quality of Water in the Cyclic Water Supply System at the Makeev Plant." *Stal*, 1958, No. 4, pp. 379–383. (£2 10*s.* 0*d.*)

987. LIHL, F., and P. ZEMSCH: "Cold Rollability of Transformer Steels containing more than 3·3%Si." *Arch. Eisenhüttenwesen*, 1955, Oct., pp. 599–602. (£4)

989. CHUKHANOV, S. F.: "The Role of the Carbon Dioxide Reduction Reaction in the Combustion of Coke." *Brennstoff-Chemie*, 1957, Oct. 16th, pp. 289–297. (£6)

991. SHAPOVALOV, M. A.: "The Introduction of Reducing Gases into the Hearth of a Blast-furnace." *Stal*, 1958, No. 5, pp. 385–390. (£4)

996. LISSNER, O.: "New Experimental Results concerning the Importance of the Surface Effect on Fatigue." *Jernkontorets Ann.*, 1957, No. 7, pp. 380–389. (Sequel to article in *Jernkontorets Ann.*, 1956, pp. 360–371—D.S.I.R. translation TRA/2784.) (£3)

1010–1012. Papers presented at the Special Meeting in Liège and abstracted in *J.I.S.I.*, 1958, June, pp. 109–110. They will be published in the *Iron and Coal Trades Review* later, but are meanwhile being included in the Translation Service at reduced prices.

1010. KOSMIDER, H. *et al.*: "The Refining of Low Phosphorus Iron in the Bottom-blown Converter." (£1 10*s.* 0*d.*)

1011. ALLARD, M.: "French Experience with the Bottom Blowing of Basic Bessemer Converters." (£1)

1012. TRENKLER, H.: "Refining Iron with 0·5–1·5%P by the LD Process." (£2)

1022. KRÄCHTER, H.: "A New Method for Measuring Compressive Forces with Ultrasonics." *Z. Maschinenbau u. Fertigung*, 1958, (5), pp. 246–248. (£2 10*s.* 0*d.*)

1024. HOENES, D., and G. VOLKERT: "The Metallurgical Behaviour of Chrome Ores." *Arch. Eisenhüttenwesen*, 1954, Jan./Feb., pp. 1–10. (£7)

1025. SAMARIN, A. M.: "The Vacuum Deoxidation and Desulphurization of Transformer Steel." Chapter I of "The Application of Vacuum to Steel-melting Processes," Moscow, Metallurgizdat, 1957, general editor A. M. Samarin, pp. 3–14. (£4 10*s.* 0*d.*)

1026. MATTHIJSEN, M. J. C.: "Sintered Ceramic Chiselling Materials." Parts I and II. *Metaalbewerking*, 1958, No. 22, pp. 452–457; No. 23, pp. 467–470. (£5 10*s.* 0*d.*)

1027. LEITNER, K.: "Introduction of Suspended Flat Roofs for Open-hearth Furnaces." *Radex Rundschau*, 1958, (3/4), pp. 146–153. (£3 15*s.* 0*d.*)

1033. KUDELYA, E. S.: "The Spectral Analysis of Fused Welding Fluxes." *Avtom. Svarka*, 1957, No. 1, pp. 73–76. (£1 10*s.* 0*d.*)

1036. SCHMAHL, N. G., *et al.*: "The Rate of Scaling of Pure Iron in Oxygen at Reduced Pressures and in Carbon Dioxide." *Arch. Eisenhüttenwesen*, 1958, No. 3, pp. 147–152. (£3 10*s.* 0*d.*)

553. LIHL, F., and P. ZEMSCH: "The Effect of Annealing Conditions on the Core Loss of Hot-rolled Transformer Sheet." *Arch. Eisenhüttenwesen*, 1955, Sept., pp. 535–540. (£4) (*See also* No. 987).

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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*Abstracts, the reference to which is marked with an asterisk are, or are to be made available as translations.

MINERAL RESOURCES

Tracing Ore Boulders as a Prospecting Method in Canada. A. Dreimanis. (*Can. Min. Met. Bull.*, 1958, **51**, Feb., 73–80).

The Caland Project at Steep Rock Lake. P. D. Pearson. (*Eng. J.*, 1957, **40**, Nov., 1657–1664).

The Wise Use of Our Natural Resources. C. C. Furnas. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 169–184). A review of U.S. iron ore resources.

An Introduction to the Geology and Mineral Resources of the Continental Shelves of the Americas. J. Trumbull, J. Lyman, J. F. Pepper and E. M. Thomasson. (*U.S. Geol. Survey Bull.* 1067, 1958, pp. 92). A note on the iron ore of Bell Island, Newfoundland is included.

History of Mining Exploration, Bathurst-Newcastle District, New Brunswick. G. S. MacKenzie. (*Can. Min. Met. Bull.*, 1958, **51**, Mar, 156–161). Magnetite and pyrites and other sulphide minerals occur.

Chile Exports its Iron Ore. O. H. Leonardos. (*Eng. Min. e Met.*, 1957, **26**, Oct., 193–194). An outline of the mineral resources of Chile, and the history of their development and disposal.

New Zealand's Iron Ores. (*Brit. Steel.*, 1958, **24**, Feb., 38–39). Occurrences of titanomagnetite, ilmenite and limonite are noted and a brief account of attempts to establish an iron industry is given.

Chromite Deposits of Southeastern Manitoba. J. F. Davies, (*Can. Min. J.*, 1958, **79**, Apr., 112–114).

ORES—MINING AND TREATMENT

Dragonby Mine. (*Mine Quarry Eng.*, 1958, **24**, Jan., 2–8, Feb., 46–51; Mar., 104–110). The origin and development of the mine operated by the United Steel Cos., roof support methods and underground loading and transport, and pumping, ventilation, surface handling and safety and welfare are described.

Study of Some Low-Silica Iron Ores of the Roumanian Republic. M. Ispas. (*Acad. Romine Met.*, 1957, **2**, (3), 311–319). Ores from Moneasa and Palazu were reduced in H_2 or methane and compared with Ghelari ore. Temperatures of 650° and 850° C were employed with 0·3 l. gas per min and a particle size of 5 mm.

The United States Have Available Colossal Reserves of Iron Ore, Only Inferior to those of Brazil. (*Eng., Min. e Met.*, 1957, **26**, Sept., 125–127). The actual and potential reserves of iron ore in the United States are compared with those of Brazil.

The Export of Iron Ore through the Port of Itacuruçá. (*Eng., Min. e Met.*, 1957, **26**, Sept., 153–156). The proposed construction of a port at Itacuruçá for the export of iron ore is discussed.

Ocean Iron Ore Carriers—Design Considerations. J. Lenaghan. (*Trans. Inst. Nav. Arch.*, 1957, **99**, 311–325). **Design and Operation of an Ore Carrier Built Abroad.** R. Atkinson. (533–577). An account of S.S. *Sunrip*, built at Quebec, is given.

Thawing of Frozen Ores in Heated Buildings. N. A. Likhid'ko. (*Metallurg*, 1957, (12), 34–35). This is a brief description of special water sprays for protecting parts of rolling stock while their ore-loads are being thawed in heated buildings. The higher operating temperatures permissible have led to considerable economies.—S. K.

Physical Concentration of Manganese Carbonate Ores. L. Burnóczky. (*Koh. Lapok*, 1957, **12**, June, 240–246). Hungarian grey and brown Mn carbonate ores of a particular size grading were washed, calcined and submitted to magnetic separation. Separate fractions rich in iron or Mn respectively were thus obtained of composition suitable for smelting. The slime from washing contains a considerable quantity of Mn. It can be worked-up chemically to electrolytic Mn or Mn compounds, without drying or grinding.

A Contribution to the Metallurgical Assessment of Iron Ores. W. Zimmer. (*Neue Hütte*, 1958, **3**, April, 233–235). The Fe content of an iron ore does not alone determine its value: decisive importance attaches to slag-forming agents. A formula has been developed that takes smelting in the blast furnace into account and provides a metallurgically accurate and unambiguous value.—L. J. L.

The Technology of Preparation of Iron Ores in Iron Works. V. I. Markin and A. K. Shaposhnikov. (*Metallurg*, 1956, (6), 12–14). Stock yard practice in the Chelyabinsk Works is described. By an appropriate bedding practice, variations in the iron and silica contents of ores were considerably reduced.—V. G.

Upgrading Cobalt-Nickel Stockpiles by the Roast-Flotation Process. M. M. Fine, G. J. Vahrenkamp, A. W. Lankenau and O. N. Moreland. (*U.S. Bur. Mines Rep. Invest.*, 1958, Feb. (5388), pp. 10). A report of a laboratory study. Optimum conditions were not established but considerable beneficiation was achieved.

Limits and Possibilities of Modern Methods of Preparation. H. Kirchberg. (*Neue Hütte*, 1958, **3**, Jan., 1–9). A discussion is presented of the problems of ore preparation; pre-concentration of low-grade ores by heavy-media methods; dry ore-dressing methods in arid regions; concentration of low-grade siliceous iron ores; dressing of deposits other than ores; mechanization of grading methods and modern methods of controlling preparation.

Materials Handling Plant and Stock Yards for Iron Ore on Its Way from the Mine to the Works Own Harbour. K. Rosenbaum. (**Stahl u. Eisen*, 1958, **78**, Apr. 17, 475–483). Modern ore-handling plant at the various stages during the transport of iron ore from the mine to the works harbour is discussed. The need to modernize these plants and to attain close co-operation between all the partners involved in the transport and handling of iron ore in order to reduce costs is stressed.

Upgrading Iron Ore by Fluidized Magnetic Conversion. R. J. Priestly. (*Blast Furn. Steel Plant*, 1958, **46**, Mar., 303–306). A description of the Fluo Solids process for magnetic roasting and beneficiation of low grade ores is given.—B. G. B.

Disruption of Ores by H. F. Electromagnetic Fields. M. A. Gintsburg. (*Izvest. Akad. Nauk, Otdel. Tekhn.*, 1957, (10), 93–95). Notes are given on a new method for breaking up rocks and similar materials through uneven heating by means of a H.F. magnetic field. The work was carried out on specimens of iron ores from the Kursk Magnetic Anomaly, consisting of quartz, magnetite, hematite, amphiboles and carbonates. Deep cracks were produced and the specimen became permanently brittle. Uniform and non-uniform fields were tried and the time for the appearance of the first crack, the mean temperature of the specimen and details of the field are given for each variant. Energy consumption for disrupting a 500-kg specimen is estimated at 1·5 KWH.—S. K.

Ore Preparation and Sintering Plants in the Danube Iron and Steel Works. I. Raabe.

(*Koh. Lapok*, 1957, **12**, Aug.-Sept., 378–383). A comprehensive description is given of the ore preparation and sintering plants in the Danube Iron and Steel Works in Hungary.

The Second Symposium on the Sintering of Iron Ores. (*Mét. Constr. Mécan.*, 1957, **89**, June, 527–537; July 621–631). Short summaries are given of papers presented at the second sintering symposium held in Paris in May 1957. They include papers on: fundamental study of heat transfer and combustion, thermal balance, removal of sulphur and other impurities, desulphurization of French ores, definition of sinter strength, factors influencing the physical strength of sinter, mineralogical composition of sinter, increase in sinter output at Appleby Frodingham, sinter plant assessment trials, agglomeration in a rotary kiln.—B. G. B.

Economic Problems in the Production of Blast-Furnace Sinter. F. Bernat and F. Jirsák. (*Hutn. Listy*, 1958, **13**, (2), 105–112). [In Czech]. The economics of sintering are considered, particularly the variation of the cost of production as a function of the ore quality, iron content of the ore, and degree of ore enrichment attained. For optimum effectiveness of the sintering process the relation between yield and iron content in the ore has to be determined empirically. The sintering process is shown to be cheaper than was thought hitherto; a new assessment of costs would be possible if there were a big increase in the demand for sinter in steelworks. This is not envisaged for the near future.—P. F.

Means of Eliminating Stoppages in Sinter Plants. D. P. Pritykin and A. V. Drimbo. (*Stal'*, 1958, (3), 202–206). Redesign of charging carriages, screening, grinding, crushing and mixing equipment at Zaporozhstal, and making the disc or plate seeders watertight are described.—B. S.

Experiments on the Removal of Arsenic from Iron Ore During the Sintering Process. E. Mazanek and R. Benesch. (*Hutnik*, 1957, **24**, Feb., 45–47). [In Polish]. The authors review and discuss various methods for the removal of As from iron ore. They tabulate the results of their own experiments and come to the following conclusions: 1. During the sintering process 20–33% of the original As content was removed. 2. Raising of temperature by adding more coke did not influence the removal of As. 3. Increase of alkali had a negative effect on the removal of As. 4. Addition of NaCl was very effective: 70–80% of the original content of arsenic was removed. 5. Addition of NaCl to the alkaline charge was disappointing, only 3–5% of the As was removed. 6. Addition of S had no effect on the removal of As.

Ferrocoke. E. Mazanek and R. Benesch. (*Hutnik*, 1957, **24**, March, 89–92). [In Polish]. The authors investigated the suitability of briquettes made of iron ore and coke for charging blast furnaces. The composition was varied from 67% to 25% of coke. They were prepared by three methods: hand made, pressed under 5 atm. and pressed under 400 atm. On the basis of these experiments the following recommendations are put forward: 1. The pressure should be as high as possible; 2. heating temperatures of 900–1000° C for about 30 min should be used; 3. Coke concentration should be 25%.

The Mechanism of the Strengthening of Pellets by Roasting. A. N. Pokhvisnev and B. A. Savel'ev. (*Stal'*, 1958, (2), 105–109). In the roasting of pellets of magnetite concentrates the magnetite should be oxidized as rapidly and completely as possible in a high O_2 atmosphere at a high temperature and the haematite formed should recrystallize. Roasting can take 10–30 min depending upon various factors. The temperature should be between 1200–1300° but both time and temperature can be reduced by crushing before concentration. Strengthening begins above 1300° C.—B. S.

Work of the Ore, Coke and Pig Iron Section of I.R.S.I.D. P. Emery. (*Centre Doc. Sidér. Circ.*, 1957, **4** (9), 1845–1852). The activities of this section include the beneficiation of low grade French ores, direct reduction and the sintering of iron ores. Brief mention is made of work being done on these subjects.—B. G. B.

FUEL—PREPARATION, PROPERTIES AND USES

Present and Potential Uses for Coal in the Canadian Metallurgical Industry. J. H. Walsh, J. C. Botham and H. P. Hudson. (*Can. Min. Met. Bull.*, 1958, **51**, Feb., 81–88). Statistics for coal and iron production are given and alternatives to the blast furnace briefly reviewed including sponge iron processes. (82 references).

We Have Plenty of Good Coking Coal. P. S. Savage. (*Steel*, 1958, Feb. 34, 78–80). Known reserves of coking coal are stated to be greater than ten years ago. Reasons cited include new mining methods, techniques for using high volatile coals, better blending, the addition of inerts, and the desulphurization of iron outside the blast furnace.—A. G.

Mayer's Curves For Measuring the Possibilities for Coal Washing. C. Bertrand y Bertrand. (*Inst. Nac. Carbon Bol. Inf.*, 1957, **6**, Nov.-Dec., 253–273).

Reactions of Sulphur in Coal During the Coking Process. Tests With the Radioactive Isotope 835. H. J. Reintjes. (*Tech. Mitt.*, 1957, Dec., 270–280). This paper describes the apparatus and method used for these tests, followed by a discussion of results obtained. Reactions of pyrites and sulphates in the coal were studied directly by means of ^{35}S, the behaviour of organic sulphur being calculated by difference. (15 references).

Study of Swelling Pressure (Driving Phenomenon) of Coals with Special Reference to Japanese Coals. T. Iwasaki. (*J. Inst. Fuel*, 1957, **30**, Nov., 602–608).

The Production of Blast Furnace Coke at High Coking Rate. E. E. Brady. (*Blast Furn. Steel Plant*, 1957, **46**, Jan., 54–59). A description is given of the coke oven practice at the Cleveland Coke and Coal Chemical Works, U.S.A., where acceptable coke has been produced at a coking rate of 1·2 in/h.

Practical Experience in the Current Use of H.C. Coke. R. Ziegler. (*Giesserei*, 1958, **45**, Feb. 27, 109–113). The results are discussed of the evaluation of a questionnaire to various Austrian foundries using high carbon coke. An average increase in production of 17% was obtained by the use of the coke. Other advantages included a smaller coke charge and increased iron temperature. Some disadvantages of the material were pointed out.

Conference on Energy. Metz 6 June, 1957. (*Rev. Mét.* 1958, **55**, Feb., 179–185). A summary of 8 papers on energy problems and balances of blast furnace and basic Bessemer steelworks is given. **Economy in Metallurgical Coke.** C. G. Thibaut. **Consumption of Energy in Small and Large Blast Furnaces Compared.** M. Gérard. **Study of the Factors on Which Gas Consumption Depend in Blast Heating for Blast Furnaces.** D. Sanna. **Energy Balance of a Cast Iron Works.** J. Szczeniowski. **Energy Balance for Converters.** P. Boutonnet. **Thermal Balance in the Fusion of Scrap in the Blast Furnace and Basic Bessemer Convertor.** G. de Rousiers. **Consumption of Energy in a Basic Bessemer Plant.** H. Junk. **The OV Process Offers a Solution to the Problem of Recovering the Heat Lost in the Basic Bessemer Flame.** M. Daubersy.

AIR POLLUTION AND SMOKE

Instruments for Measuring Small Quantities of Sulphur Dioxide in the Atmosphere. W. G. Cummings and M. W. Redfearn. (*J. Inst. Fuel*, 1958, **30**, Nov., 628–635). Two continuous recorders, one portable, are described, developed by the Central Electricity Research Laboratories.

The Nuisance of Metallurgical Fumes in the Industrial District of Silesia. B. Litonski. (*Hutnik*, 1957, **24**, March, 111–116). [In Polish]. The problem of poisonous fumes and dust from the metallurgical industry dispersed in the atmosphere is discussed. The source of these exhalations, their properties and the effect they have on the district and its inhabitants are described. Recommendations which will give the best sanitary protection are suggested.

'Serseal'—Development in Fume Prevention. R. E. Shaw. (*Corros. Techn.*, 1958, **5**, Mar., 79–80). The author describes an investigation carried out in I.C.I. Laboratories in which it was found that steam and fumes could be eliminated from certain metal pretreatment baths by sealing the surface with 'Serseal'—an inert liquid layer. Three examples are given of the successful application of a 'Serseal' layer to Granodine (phosphate) tanks and an alkaline bath.—L. E. W.

Dust and Fume Control in a Modern Melt Shop. C. W. Finkl. (*A.I.M.M.E., Elec. Furn. Steel Conf. Proc.*, 1956, **14**, 272–280). A bag-type air filter installation is described.

Automation Provides the Key to More Efficient Gas Cleaning. C. E. Beaver. (*Blast Furn. Steel Plant*, 1958, **46**, Mar., 318–320). A newly developed electronic feed-back control for Cottrell electrostatic gas cleaning plants is briefly described.—B. G. B.

TEMPERATURE MEASUREMENT AND CONTROL

Suction Pyrometers. M. Rivière, G. Urbain and R. Kissel. (*Chal. et Ind.*, 1957, **38**, Dec., 318–324). The theory, construction and applications of suction pyrometers are discussed. Satisfactory and reproducible results are obtained in measuring gas temperatures provided certain precautions are taken. (13 references).—R. P.

Can the Temperature of Iron Baths be Measured Continuously (*J. d'Inf. Tech. Indus. Fonderie*, 1957, Aug., 7–9). A brief review of the application of Pt–Pt.Rh thermocouples, total radiation pyrometers and optical pyrometers for measuring the temperature of liquid iron is presented.

REFRACTORY MATERIALS

The Refractory Brick and Its Chemical, Physical and Mechanical Properties. H. Detaille. (*Rev. Univ. Min.*, 1957, 9th series, **13**, Oct., 637–650). Factors influencing the formation of a liquid phase during the heating of aluminosilicate bricks and of a vitreous phase during cooling are discussed. The influence of the vitreous phase on the mechanical properties of refractory bricks is considered in detail. Results obtained at the Institut National des Silicates during the study of aluminosilicate type bricks with varying alumina content are described.—B. G. B.

Notes on the Manufacture of Silica Bricks. A. Jourdain. (*Centre Doc. Sidér. Circ.*, 1958, **5**, (2), 425–449). A comprehensive review of the theory and practice of silica brick manufacture is presented.—B. G. B.

Basic Materials and Their Use in Steelmaking. H. Reisch. (*Centre Doc. Sidér. Circ.*, 1957, **4**, (9), 1863–1871). A review of basic refractories and their application is presented. The properties and uses of a wide range of materials are summarized in tabular form.—B. G. B.

Standardisation of Refractories. (*Centre Doc. Sidér. Circ.*, 1958, **5**, (2), 403–406). A report of a meeting held to discuss standardization of refractory materials for the French steel industry is given.—B. G. B.

A Modern Refractory Material. L. Longchambon. (*Rev. Univ. Min.*, 1957, 9th series, **13**, Oct., 619–637). An illustrated description of the development and use of refractory cements is given. The production of large precast shapes is discussed. Numerous examples showing the advantages of refractory concrete construction are shown.

Utilisation of Corhart Refractories in Steelmaking. F. Gely. (*Centre. Doc. Sidér. Circ. Inform. Tech.*, 1957, **4**, (12), 2459–2464). A review of the application of this electrocast type of refractory is presented. It has a very high refractoriness and a high resistance to corrosion. The porosity is zero.—B. G. B.

Russian Resolutions in Refractories Technology. K. Shaw. (*Refract. J.* 1958, **34**, Feb., 72–74). A brief review from recent publications.

Forsterite. J. Montagnier. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, **4**, (12),

2455–2457). A review of the occurrence, manufacture and properties of forsterite refractory bricks is presented.—B. G. B.

The Silicates. R. De Reytere. (*Rev. Univ. Min.* 1957, 9th series, **13**, Oct., 599–609). The properties of the raw materials used in the manufacture of refractory bricks are first discussed. The phase changes which occur during the heating of siliceous, aluminous and clay minerals are considered. Processes for the manufacture of siliceous, alumino-silica and alumina bricks are described together with the properties and uses of these bricks.

Reactions in Silica–Alumina Mixtures. R. R. West and T. J. Gray. (*J. Am. Ceram. Soc.*, 1958, **41**, Apr., 132–136). Pure SiO_2–Al_2O_3 mixtures were examined and greatest reactivity was found at $2Al_2O_3$, SiO_2 rather than at the mullite composition, but that reactivity depends also on the Al_2O_3 allotrope used. A sharp exothermal peak at 980° C is found and an explanation advanced postulating three simultaneous reactions.

The Problem of Hot Strength in Basic Refractories. W. F. Ford. (*Refract. J.*, 1958, **34**, Feb., 55–65; discussion 67–69). An annotated review of previous work with suggestions for further investigations. (17 references).

Blast Furnace Refractories at Knutange. Pastor. (*Centre Doc. Sidér. Circ.*, 1957, **4**, (11), 2267–2291). An illustrated review of the construction and performances of refractory linings in the Knutange blast furnaces is presented.—B. G. B.

The Use of Unburnt Magnesite–Chrome Brick for Furnace Roofs. B. P. Okhrimovich, A. E. Pribytkov, A. I. Uzberg and P. A. Rumm. (*Stal'*, 1958, (2), 126–130). The wear of unburnt bricks does not differ from that of burnt bricks and occurs by peeling. The rate is 1–9% greater and in the roofs of electric furnaces, twice as great. It is suitable for use in the O.H. furnace if burnt brick is used for the parts subject to maximum wear and for suspension. Further study of quality and conditions for use is required.—R. S.

High-Alumina Linings. V. J. Howard. (*A.I.M.M.E. Elec. Furn. Steel Conf. Proc.*, 1956, **14**, 254–259). **Ganister versus High-Alumina Linings.** C. A. Faist. (259–261). Ladle refractories for the steel foundry are reviewed and an account of experimental work is given.

Zirconite Ladle Linings. W. D. Emmett and V. E. Zang. (*A.I.M.M.E. Elec. Furn. Steel Conf. Proc.*, 1956, **14**, 246–250); **Zircon Ladle Lining for Basic Steel.** W. A. Koppi. (250–254); Foundry uses are reviewed. The zircon replaced silica with advantage.

Mineral Placement of the Constituents in Five Types of Basic Brick. N. B. Dodge. (*Amer. Ceram. Soc. Bull.*, 1958, **37**, Mar., 139–143).

IRON AND STEEL, GENERAL

The Steel Industry from the Canadian Point of View. V. W. Scully. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 161–167). A review of output and developments.

Recent Progress in the Iron and Steel Industry. A. Desoer. (*Usine Nouv.*, 1958, **14**, Apr. 10, 23, 25). A brief review of advances with the blast furnace and alternatives, basic O.H. and basic converter practice, the electric furnace and the rolling mill.

Société Metallurgique de Champagne. (*Aciers Fins Spéc.*, 1958, March, 114–115). The historical development and current status of the company are briefly described.—A. G.

Steelmaking in Northern Spain. J. Sanz y Diaz. (*Met. Elect.*, 1958, **22**, Mar., 87–90). An outline is given of the iron ore production in Northern Spain, followed by a brief account of the development of the steelmaking industry in that region in recent years.—L. D. H.

Description of the Industrial Complex of the Empresa Nacional Siderúrgica SA of Avilés. (*Dyna*, 1958, **33**, Mar., 139–192). A detailed description of the manufacture and processing of iron and steel and the by-products plant at these works is given.

Transcendent Change in the Panorama of the [Spanish] Iron and Steel Industry. J. G. Carvaja. (*Met. Elect.*, 1958, **22**, Feb., 67–75). [In Spanish]. This commentary was prompted by the coming into operation of the first blast furnace at Aviles (National Steel Co.) and, in it, markets, demands, production, the vitality of private industry, new developments and hopes for the future are discussed.—P. S.

Expansion of the Iron and Steelmaking Industry in São Paulo. R. Jafet. (*Eng., Min. e Met.*, 1957, **26**, Sept., 143–150). The history, development, present position and prospects of the steelmaking industry of São Paulo are discussed.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG-IRON

Blast Furnaces–What Happened in '57 and What's Ahead in '58. B. F. Ironman. (*Blast Furn. Steel Plant*, 1958, **46**, Jan., 46–48). A short review of present and future blast furnace practice in America is presented.

Operational Results at the Azovstal' Works in 1955 and Tasks for 1956. Ya. P. Kulikov. (*Metallurg*, 1956, (4), 3–5). Progress in the output achieved during 1950–1955 is outlined. The outputs increased; in the case of pig iron by 32·9%, steel by 68·1% and rolled products by 79·2%. Measures taken which led to the above increases are briefly described. It is planned that during 1956 the outputs of pig iron, steel and rolled products will increase by 5·4, 11·6 and 11·2% respectively compared with the 1955 figures.—V. G.

Modern Trends in Iron and Steel Making. E. Klein. (*South African Mech. Eng.*, 1958, **7**, Feb., 203–219, discussion 220–224). A general illustrated review of blast furnace design and physical burdening, high top-pressure and sintering and pelletizing and ore beneficiation. The low-shaft furnace is briefly considered. Steel making is then surveyed with regard to the L.D., Rotor, Kaldo and electric arc furnace processes.

Furnace Lines, Operating Methods and Theory of Southern and Northern Blast Furnace Practice. J. R. Hunt. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 369–407, discussion 407–414). Profiles of furnaces from 1883 are shown and practice is reviewed in some detail.

Screening of Blast-furnace Burden Materials. H. N. Wilkinson and E. E. Farmer. (*J.I.S.I.*, 1958, **190**, Sept., 55–71). [This issue].

Sub-Commission on Iron Quality. (*Centre Doc. Sidér. Circ.*, 1958, **5**, (2), 367–371). A report on a meeting held between blast furnace and Bessemer plant operators to discuss pig iron quality is presented.—B. G. B.

Elimination of Copper from Molten Pig Iron. K. Ueno, O. Yasukabe and M. Inoue. (*Tetsu-to-Hagane*, 1957, **43**, Mar., 265–6). Removal with Na_2S—Na_2SO_4 is examined. Artificial samples with added Cu were used in a laboratory furnace at 1300–1400° C. Crystalline hydrated sulphide or anhydrous sulphate were used. Decreased amounts decrease degree of Cu removal and period of holding had little effect.

Desulphurising Pig Iron Outside the Blast Furnace. M. I. Gromov, L. M. Tsylev, A. M. Kakunin, V. I. Kotov and V. N. Kalorulin. (*Metallurg*, 1958, (3), 3–6). The best method is said to be the use of a rotary furnace developed at Novo Lipetsk. The main factors are atmosphere composition, amount and lump size of lime and coke breeze, analysis of the iron, temperature, rate of rotation and refractory lining. The use of tea-pot ladles and the blowing in of CaC_2 or adding it in the launder and the use of a special coffee-pot ladle are described. Lime with a minimum of CO_2 and SiO_2 and below 1 mm size up to 1% of the weight of iron is recommended, creating a reducing atmosphere with 1–3 mm coke breeze.—R. S.

The Use of By-Product Nitrogen from Oxygen Plants in Blast Furnaces. A. P. Korshunov. (*Stal'*, 1958, (3), 208). Saturated steam is used to prevent air entering the region between the bells in a blast furnace and to safeguard against explosion. The possibility of explosion cannot, however, be completely excluded since the oxygen content of the gaseous mixture is sometimes as high as 13%. In addition, the presence of H_2 and water vapour increases the danger of ignition. The use of steam has a deleterious effect on the operation of top gear. The Americans found that the danger of explosion from a mixture of CO and air can be eliminated by adding four times the volume of N_2 to the mixture and sixteen times the volume of N_2 for a mixture of air and H_2. Since many Russian works have O_2 plants which produce N_2 as a by-product, the replacement of blast furnace gas by N_2 for equalizing the pressure in the region between the bells removes the danger of explosion, reduces steam consumption, eliminates gas losses and reduces top gear wear. The pressure drop between the hot blast and the top gases becomes more constant. Pure dry N_2 can also be used for blowing out mains, dust catchers and scrubbers when furnace stoppages occur.—R. S.

Operating Experiences of a Blast-Furnace Foreman, P. P. Lygun. V. D. Kichko. (*Metallurg*, 1956, (6), 14–16). Procedures used by blast furnace foreman P. P. Lygun and his team in taking over shift, preparations for casting, care of tap hole, slag notch, iron and slag runners and blast furnace equipment are outlined.—V. G.

Indicating the Limiting Level of Water in a Scrubber. F. P. Vasyutin, V. M. Dement'ev, K. S. Klempner and V. A. Machkovskii (*Metallurg*, 1958, (3), 6–7). A floating-type regulator is illustrated for use with high top pressure where there may be sudden falls to atmospheric pressure of 7000–10,000 mm w.g. A method using radioactive Co was also worked out.—R. S.

Iron and Phosphate Slag from By-product Ferrophosphorus. J. M. Potts, W. C. Scott, jun., J. V. Campbell and J. A. Wilbanks. (*J. Electrochem. Soc.*, 1958, **105**, Mar., 148–151). A furnace with graphite walls and magnesite hearth was devised to melt Fe–P with calcined siliceous Fe ore and CaO producing Fe with 0·5% P and a slag with 22% citrate-soluble P_2O_5.

PROPERTIES, TREATMENT, AND USE OF SLAGS

Slag Production Plant at Teesport. (*Engineer*, 1958, **205**, Apr. 18, 577–582). Uses are outlined and an account is given of a new plant producing 15000 t weekly graded in 10 sizes. The slag is crushed, screened, coated with road tar and loaded directly into ships if required.

Experimental Studies on the Oxidising Power of Refining Slags. 1. Equilibrium Conditions of Slags in the System SiO_2–CaO–MgO–FeO–Fe_2O_3 in the Molten State, in Open Crucibles at 1550–1650° C in the Absence of Metallic Iron. T. T. Négresco and M. Bolgill. (*Rev. Mét. Bucarest*, 1956, **1**, 5–32). [In French]. Earlier work in MgO crucibles did not take account of the MgO dissolved, assuming that it was chemically equivalent to CaO. In fact the compounds formed are 3 CaO, 5 SiO_2 and 4 MgO, 5 SiO_2. The expression previously obtained is therefore revised and experiments on a new series of slags with varying amounts of CaO were used to confirm the new expression. The physico-chemical interpretation of the findings is discussed. The activities of the above silicates and 3 FeO, 8 SiO_2 are shown to correlate with cationic size.

A Contribution to the Study of the Viscosity of Basic Open-Hearth Slags. I. Laboratory Study of Viscosity and Conductivity of Basic Slag. L. Tripsa. (*Acad. Romine Met.*, 1957, **2**, (3), 289–310). Measurements on 51 samples were made prepared by addition of Al_2O_3, SiO_2, CaO and MgO to 3 commercial slags over the range 1300–1700° C in a Tamman furnace. Exponential expressions for viscosity and conductivity with temperature are obtained. Two empirical formulæ are also given relating these properties to composition.

Capacity for Absorption of Sulphur and Constitution in the Liquid State of Blast Furnace Slags. T. T. Négrescu. (*Rev. Mét. Bucarest*, 1957, (2), 5–50). [In French]. Equilibrium diagrams are determined and the sulphur capacity of SiO_2–CaO–Al_2O_3 slags at 1500° C is derived. The SiO_2–CaO–MgO–Al_2O_3 system is then considered from 1460–

1575° C and the effect of temperature on the SiO_2–CaO–Al_2O_3 system is then worked out and related to the activity of the CaO. More complex systems are then dealt with and partial diagrams are shown. Calculations and a nomogram for commercial slags are then made. A thermodynamic study follows and the form of sulphur present, metal'bath composition and partition coefficients are investigated. (35 references).

Basic Structure of Liquid Metallic Slags with Reference to Their Absorption Capacity for Sulphur. T. T. Negrescu. (*Met. Constr. Masini*, 1958, **10**, (1), 8–11). A series of systematic investigations extending over some years with regard to the desulphurizing properties of blast-furnace slags have given experimental results leading to the formation of some new aspects on certain problems which seemed well settled, so, for instance, the distribution coefficient of sulphur between slag and the molten metal bath, or the supposed proportionality between the basicity indices of slags and their desulphurizing capacity. The experimental results have also led to the formulation of an almost new concept of the structure of liquid metallurgical slags, which is the result of a large number of numerical determinations of what the author since 1950 has called "the absorption capacity of blast-furnace slags for sulphur." In this first instalment are considered the ternary system SiO_2–CaO–Al_2O_3, the thermodynamical concentration and activity of Ca in this ternary system, and its thermodynamical activity in the binary systen CaO–Al_2O_3.

Desulphurizing Power of Blast Furnace Slags. V. Capacity for Sulphur Absorption of Slags of the System SiO_2–CaO–FeO in the Liquid State at 1500° C. T. T. Negrescu. (*Acad. Romine Met.*, 1957, **2**, (1–2), 37–66). An equation for sulphur absorption by the SiO_2–CaO–MgO–Al_2O_3 system has been given previously. About 50 synthetic slags of the SiO_2–CaO–FeO system have now been examined and two expressions are derived, one for low FeO contents corresponding to blast furnace slags. The effects of FeO are shown to resemble those of MgO and an activity concept for the lime is developed, and the relation of the compounds formed to sulphide formation are considered. The classic activity concept is replaced by a subtracted parameter. The mechanism is shown to be not only a substitution process but also a process analogous to solvation. **VI. Absorption Capacity for Sulphur of Slags of the System SiO_2–CaO–MnO in the Liquid State at 1425° C.** ((3), 265–288). An expression is given for sulphur absorptive capacity in terms of composition related to that obtained previously, and mechanism is discussed. A summary of the previous systems considered is included and a general expression for sulphur equivalent of 100 g slag is advanced. A nomogram is included and the validity of calculations based either on partition coefficient or on basicity index is shown.

Examples of the Application of the Ionic Theory of Slags to Represent Quantitatively the Reactions Between Slag and Metal. A. Staronka. (*Hutnik*, 1957, **24**, Feb., 51–55). [In Polish]. Basicity of slags according to the molecular and ionic theory is defined. Chemical equilibrium of sulphur between basic slag and metal is calculated on the basis of the ionic theory, and shown to be more consistent with the experimental results.

Plant for Production of Slag Wool from Blast-Furnace Slags. L. V. Brodetskii. (*Metallurg*, 1957, (12), 36). A very brief account is given of a method of slag-wool production from blast-furnace slag which has not previously solidified. The cost of the installation is said to be 1/7 of that in which solidified slag is remelted in a cupola.—S. K.

Quick Determination of Slag Basicity by Means of Measuring the Heat of Neutralisation. I. Sajó. (*Koh. Lapok*, 1957, **12**, July, 287–289). A method is described for quick determination of the basicity, FeO and SiO_2 contents of slags by means of the heats of reaction and neutralization. The accuracy of the method is, for basicity ± 0·2, for FeO ± 1% and for SiO_2 ± 2·5%.—P. K.

WROUGHT IRON

Properties of Wrought Irons Used in Old Railway Bridges. J. Sorm. (*Hutn. Listy*, 1958, **13**, (3), 226–229). [In Czech]. Tensile tests, fatigue tests, impact tests, determination of the ductile-brittle transition temperatures and chemical analyses were carried out on samples taken from 18 railway bridges of old construction. The materials were found to satisfy the requirements relating to the carrying capacities of the bridges down to − 40° C, the principal quality variable being the phosphorus content. The properties of the wrought-irons compared favourably with those of steels now used for similar purposes.—P. F.

DIRECT PROCESSES

Processes for Direct Reduction of Iron. B. S. Old. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 203–224). Brief accounts are given of the R–N process of Republic Steel–National Lead, the H-iron process of Hydrocarbon Research–Bethlehem Steel, the Nu–Iron process of U.S. Steel and the Esso Research–Little process.

Direct Reduction is Closer. (*Steel*, 1958, **142**, Mar. 17, 102, 104, 107). A report of the papers read at the A.I.M.E. meeting in New York.

The Rotor Process. E. Spetzler. (*Neue Hütte*, 1958, **3**, Feb., 85–93). A description of the Rotor process, dealing with the construction, type of charge, furnace lining, thermal balance, cleaning of waste-gases, steel quality obtained and economic considerations.

The Kaldo Process. (*Brit. Steelmaker*, 1958, **24**, Jan., 24–25; *Iron Steel*, 1958, **31**, Jan., 18). As a result of a recent agreement with Bamag, A.G., Head Wrightson Iron and Steel Works Engineering Ltd., can offer designs and complete engineering services for the Kaldo process in Great Britain. Brief details of the plant and process are given.—G. F.

PRODUCTION OF STEEL

European Steelmaking Today. A Mcleod. (*Iron Steel Eng.*, 1958, **35**, Feb., 133–159). This comprehensive review covers recent plant developments in Britain, France, Holland, Switzerland, Belgium, Italy, Austria, Norway, Sweden, Luxemburg and Germany. The European Coal and Steel Community and Common Market are discussed. Special details are given of research and development, raw materials (including low-shaft smelting and all-sinter burdens), blast furnaces, steelmaking (including "cyclosteel") and mechanical working (including automatic gauge control). (52 references).—K. E. J.

Impressions of European Steelmaking. M. B. Antrim. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 613–625). Visits to Sweden, Denmark, Germany, Austria, Belgium and Great Britain are briefly reported and matters of interest observed are referred to.

Survey of Recent Developments in the Steel Industry. F. De. Carli. (*Fonderia*, 1957, **6**, Jan., 29–38). [In Italian]. A brief review is given of the major new developments in the steel industry, notably: ore beneficiation process, the uses of oxygen in steelmaking, new design in O.H. furnaces, top-blown converters, vacuum casting, the very large electric furnace and continuous casting of steel.—M. D. J. B.

Evolution and Recent Progress in Steelmaking. A. Descer. (*Rev. Soc. Roy. Belge Ing. Indust.*, 1957, Nov., 399–417). An historical review of the early development of iron and steelmaking in Europe is first presented. The rapid increase in steel production since 1900 is surveyed. Recent advances in blast furnace technology and in other iron making processes are reviewed. Steel making practice is discussed, including basic O.H. electric furnace, basic Bessemer convertor and oxygen processes.—B. G. B.

The Future of Steel Making Techniques. B. Vécsey. (*Koh. Lapok*, 1957, **12**, Oct., 445–453). After giving a short review of the historical development and present stage of various steel making processes, the author deals comprehensively with the use of oxygen in steel melting. He describes the LD, Kaldo and Rotor processes and a new experimental method, used in Gutehoffnungshütte, Oberhausen, Germany, employing a tilting furnace and burning various fuels in pure O_2.—P. K.

Basic Guides to Steel Quality. (*Steel*, 1958, April 28, 106–109). For the control of steel quality the use of three elementary techniques; control charts, frequency distribution and sampling is recommended and briefly discussed.

Pneumatic Processes of Steel Ingot Production in Europe and North America. G. M. Yocom. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 81–160). A review of converter processes. The acid and basic Bessemer processes, the two L.D. plants at Linz and Donawitz and the basic oxygen plants at Dofasco, Ontario and McLouth Steel Corp., Michigan are described and the Kaldo process is also dealt with.

Low Grade Ores in North American Steel Production. (*Min. J.*, 1958, **250**, Apr. 18, 441–442). Mainly statistical with notes on the H-iron and R-N processes.

Low Capital Cost Spurs Swing to Oxygen Steel. (*Iron Age*, 1958, **181**, Feb. 6, 55–58). The growth of oxygen steelmaking capacity is described. A table specifies the type, location and capacity of plants throughout the world. Current world production of 5 m ingot tons will grow to 17 m tons in 2 years, when 60 oxygen plants will be in operation. Reasons for the expansion are: low capital cost of the plant, quality of product, improvements in oxygen supply. Some data is given on the L-D process: it requires more hot-metal in the charge than the O.H.; recent techniques allow carbon to be controlled at relatively high levels.—D. L. C. P.

Activity in Scrap Totalled 36 Million Tons in 1957. E. C. Barringer. (*Blast Furn. Steel Plant*, 1957, **46**, Jan., 52–53). A short review of the activities of the American steel scrap industry during 1957 is presented.—B. G. B.

Study of the Price Differential for Different Grades of Scrap Content of Residual Elements. Lefebvre. (*Centre Doc. Sidér. Circ.*, 1957, **4**, (11), 2231–2239). The manufacture of a low-alloy Cr–Mn steel in a 10-t electric furnace is discussed with particular reference to the influence of the type of scrap.—B. G. B.

Scientific Research in the Steelmaking Field. P. Coheur. (*Rev. Univ. Min.*, 1957, 9th series, **13**, Sept., 512–527). A review of the extent of applied and fundamental research work on steelmaking is presented. Particular reference is made to work being carried out in Belgium and the facilities available.

Location of Oxygen Plant in an Iron and Steel Works. E. G. Tokar' and A. G. Atlasov. (*Kislorod*, 1957, (6), 22–24). The atmosphere in the vicinity of steel works is usually not very greatly contaminated with acetylene. Some installations, however, can temporarily increase the acetylene content of the atmosphere and some data are given on various degrees of contamination and protective measures.

Inter-Works School on Oxygen. M. M. Kopeliovich. (*Kislorod*, 1957, (6), 40–41). A brief note is given on the work of an inter-works school set up among four Soviet steel plants to study oxygen techniques,—B. S.

The Economical Use of Manganese in Pig Iron and Steel Production. L. Visnyovszky. (*Koh. Lapok*, 1957, **12**, Jan.-Feb., 14–18). Suggestions are given for the economical use of Hungarian Mn ores in pig iron and steel production. Especially a decrease in slag quantity and adequate iron-ore preparation in the pig iron production, as well as desulphurizing of pig iron are proposed.—P. K.

The Use of Oxygen in a Modified Tilting Furnace. A. Jackson. (*J.I.S.I.*, 1958, **190**, Sept., 1–29). [This issue].

Continuous Casting at Atlas Steels Ltd., Welland, Ontario, Canada. G. C. Olson. (*J.I.S.I.*, 1958, **190**, Sept., 40–50). [This issue].

Relationship of Freezing Characteristics to Hot Tearing and Deoxidation. C. F. Christopher. (*A.I.M.M.E. Elec. Furn. Steel Conf.*

Proc., 1956, **14**, 220–245). Hot tearing susceptibility is shown to exist above the true freezing point and to be confined to a narrow temperature range primarily affected by the heterogeneous freezing point of the metal. In this range it is shown that freezing point associated with heterogeneous freezing determines the type, amount and location of deoxidation products. Charpy impact tests were used and microstructures are shown.

Some Studies on Semi-killed Steel. II. Correlation between the Condition of Sub-surface Blow-holes of Ingots and the Condition of Seams of Blooms. T. Kato. (*Tetsu-to-Hagane*, 1957, Nov., **43**, 1200–1205). [In Japanese]. Tests were made on 4-t semi-killed ingots. To prevent formation of seams in blooms, sub-surface blowholes should be within 2 mm from the skin, or else the thickness of solid skin should be more than 5 mm.—K. E. J.

PRODUCTION OF FERRO-ALLOYS

Production of Ferro-Alloys. G. Volkert. (*Iron Coal Trades Rev.*, 1958, **176**, Apr. 18, 909–913). A paper from the World Power Conference at Belgrade. Statistics for Germany and the U.S. are given, basic metallurgy is outlined and continuous processes for Si, Cr and Mn alloys, and batch methods in electric furnaces are indicated. The raw materials, power and location requirements for the setting up of a new industry are discussed.

Latest Development in the Field of Ferro-Chrome Metallurgy. G. Volkert. (*Metall*, 1957, **11**, Oct., 846–848). Process metallurgy developments are briefly described, comprising improvements of the electro-silico-thermic process and the use of an electric low-shaft furnace followed by decarburization in the solid state.—J. G. W.

Details of the Metallothermic Production of Ferro-Tungsten. A. Horváth. (*Koh. Lapok*, 1957, **12**, July, 292–300). The theoretical principles and the technique of the metallothermic production of Fe–W and W, Si, Mn and S segregation in the product are discussed. The best results were obtained by the use of 105% reducing material, containing 80–70% Al and 20–30% Si. The electric power consumption is lower than that for electrothermic Fe–W production and it depends on the shape of Al and on the amount of Si in the reducing material.—P. K.

Casting Ferro-Manganese on a Casting Machine. M. N. Marchevskii. (*Metallurg*, 1958, (3), 10). This is a brief note on the optimum conditions for casting ferro-manganese over a casting machine at Nizhne Tagil. Pig weight was 1 cwt and mould speed was 20 to 22 ft per min. A slight amount of water was used for cooling. The moulds were sprayed with milk of lime (dens. 1·2). The lime was sprayed during two complete rotations of the strand after the ladle had been teemed. FeMn losses were 2·6%. After 15 to 25 casts of FeMn, the weight of the empty ladle was increased by 10 to 15 t and it had to be replaced.—R. S.

FOUNDRY PRACTICE

The Foundry Industry in Scandinavian Countries. Z. Gorny. (*Prz. Odlew.*, 1958, **8**, (4), 107–110).

Metal Balance Gives Important Indications for Economy in Material. K. Winter. (*Giessereitechn.*, 1958, **4**, Mar., 53–57). The need for a standard nomenclature in arriving at a metal balance in casting practice is emphasized; definitions are given, and illustrative examples are discussed.

The Design of Iron Castings. M. Bertacchini. (*Fonderia*, 1958, **7**, Apr., 155–165). The article examines the possibilities offered by modern foundry techniques and discusses their practical limits of application. Mechanical characteristics, surface finish and workability are also discussed. The effect of good costing design on production costs is stressed. (7 references).—M. D. J. B.

Casting of Components Using Ultrasonics. N. P. Nikolaichik and E. N. Nikolaichik. (*Lit. Proizv.*, 1958, (2), 25). The experiments reported here show that the influence of ultrasonics promotes good crystallization and opens up the possibility of using this process in the casting of various metals and alloys in all kinds of moulds.—L. H.

The Role of Manganese and Sulphur in Cast Iron Production. M. Cseh. (*Koh. Lapok*, 1957, **12**, Oct., Öntöde, 208–210. The author, in reporting the article of W. G. Tonks, published in the Journal of Research and Development B.C.I.R.A. 1956, June, 214–225, suggests applications to Hungarian foundry practice.

Ford's New Foundry. (*Iron Steel*, 1958, **31**, Jan., 15–17). The new "Thames" foundry of Ford Motor Co. Ltd., is planned to have a daily capacity of about 400-t of castings. Brief details are given of the layout of the new foundry and the sequence of operations.—G. F.

The Design of Foundries. B. Kamenický and F. Hirsch. (*Slévárenství*, 1958, **6**, (2), 33–43). [In Czech]. A detailed critical survey is made of foundry planning methodology, based mainly on exhibits and documents shown at the International Foundry Congress in Düsseldorf in 1956.—P. F.

The Foundry in the Danube Iron and Steel Works. P. Weingartner and L. Tözsér. (*Koh. Lapok*, 1957, **12**, Aug.-Sept., 423–426). The authors describe the foundry in the Danube Iron and Steel Works in Hungary and refer to some special moulding and casting methods applied there, e.g. the use of atmospheric and exothermic feeders etc. There are three acid-lined cupola furnaces, two of 1100 mm, one of 900 mm dia. for grey iron production, and one 3·5 t basic arc furnace for steel casting.—P. K.

Gleason Works Achieves Newness in a Foundry. R. H. Herrmann. (*Foundry*, 1958, **86**, Feb., 78–88). A description is given of the lay-out, equipment, facilities and foundry practice at the new foundry at the Gleason Works of Rochester, N.Y. The foundry produces mainly grey iron castings of up to 14 t in weight.—B. C. W.

Pontiac Foundry Pours 150 V-8 Blocks Per Hour. (*Mod. Castings*, 1958, **33**, Mar., 31). A very brief illustrated description of an automatic moulding line.—B. C. W.

Rationalisation in Mechanized Foundries. G. Somigli. (*Fonderia Ital.*, 1958, **7**, Mar., 88–98). The paper discusses modern production methods and controls in mechanized foundries. The whole range of technical development and economic planning in foundry practice is received and typical layouts based on flow charts are described.

Modernization and Mechanization of a Foundry for Ingot Moulds. A. Rege and N. Monniello. (*Fonderia Ital.*, 1958, **7**, Mar., 99–104). The ariticle describes an ingot mould foundry and the improvements which brought about an increase in production from 700 t to 1500 t a month.—M. D. J. B.

Lessons in Mechanised Foundry Practice. G. Somigli. (*Fonderia Ital.*, 1958, **7**, Apr., 135–148). The first describes the origins and scope of mechanization in foundries, its importance and effect on productivity, the fundamentals of mechanical handling and the mechanization of production methods and transport. The second discusses mechanical mould preparation, pattern making, moulding sands, moulding and demoulding.—M. D. J. B.

The Present State of Development in Cupola Operation: Results Obtained with the Basic Cupola. M. Olivo. (*Fonderia*, 1958, **7**, Apr., 137–142; *Fonderia Ital.*, 1958, **7**, Mar., 83–87). The article describes practical results obtained with a basic cupola operated with cold blast and without water cooling. Certain improvements carried out on the cupola are described. The behaviour and life of the lining are discussed as well as technical data such as coke consumption, charge, fluxes, casting temperatures and plant and labour costs. (12 references).—M. D. J. B.

The Use of Cast Iron and Steel Turnings in the Cupola. (*Fonderia*, 1957, **6**, Jan., 13–18). [In Italian]. The article describes the segregation and preparation of cast iron and steel turnings for use as charge material in the cupola. The effect of small size foundry scrap containing up to 30% sand on cupola operation is also described.—M. D. J. B.

Casting Defects and their Causes. J. Drachmann. (*Gjuteriet*, 1958, **48**, Apr., 49–50). The types and causes of blowholes in various types of castings are summarized very briefly.

Considerations on the Mechanism of Solidification of Grey Cast Irons. A. De Sy. (*Fond. Belge*, 1958, **28**, Feb., 43–51). The theory of spontaneous nucleation is briefly reviewed and the solidification of a eutectic is discussed with particular reference to the differences between normal and abnormal eutectics. The solidification of the eutectic in grey cast irons is then considered and a mechanism advanced to explain the development of graphite rosettes, i.e. A.S.T.M. type B graphite.—B. C. W.

Solidification of Various Metals in Ingot and Sand Moulds. W. S. Pellini. (*A.I.M.M.E. Elec. Furn. Steel Conf. Proc.*, 1956, **14**, 48–91). Studies of the solidification of steel in a sand mould fitted with an array of thermocouples are reported. Many cooling curves are shown and conditions are discussed. Similar data for grey and nodular irons, stainless steels and non-ferrous metals are then given. Simple shapes are then considered and foundry characteristics are brought in. (26 references).

Shrinkage, Shrinkage Cavities and Surface Holes in Magnesium Iron. K. I. Bashchenko, R. P. Todorov and V. V. Zhizhchenko. (*Lit. Proizv.*, 1958, (2) 14–20). These defects are considered in detail with the factors influencing them and the data of the investigations are catalogued and graphically recorded.

Some Remarks on the Surface Oxidation of Liquid Grey Iron. G. Nándori. (*Koh. Lapok*, 1957, **12**, March, Öntöde, 49–53). The characteristics of the oxide–silicate film on the surface of liquid grey iron are similar to those of acid O.H. slags. The composition of this layer affects the porosity of the casting. The Mn content of grey iron protects the Fe against oxidation.—P. K.

Observations on Pinhole Defects in White Iron Castings. R. W. Heine. (*Mod. Castings*, 1958, **33**, Feb., 53–57). Four types of pinhole defects in white iron castings are distinguished and their basic causes discussed. Particular attention is paid to reaction pinholes caused by slag in the metal.—B. C. W.

Effect of the Size of K-Bar Test Castings on Their Shrinkage Defects. T. J. Szajda. (*B.C.I.R.A. J. Res. Dev.*, 1957, **7**, Dec., 110–128). The influence of the size of K-bar test castings and of the pouring temperature in the range 1415° to 1470° C upon the occurrence and location of a number of shrinkage defects has been studied. Different sizes and designs of K-bar test castings are particularly prone to certain shrinkage defects. It is suggested that a set of four different sizes would constitute a sensitive test, particularly for drawing defects.—B. G. B.

Exudation and Expression in Grey Cast Iron Cast in Permanent Moulds. W. Haude. (*Giessereitechn.*, 1958, **4**, Mar., 58–59). The causes of exudation from castings made in permanent moulds are discussed. The phenomena are mainly due to the action of the mould, although in some cases segregation may be responsible. Remedies are suggested.

Contribution to the Problem of Surface Defects in Steel Castings. J. Czikel. (*Giessereitechnik*, 1958, **4**, Feb., 32–34). The problem of surface defects in steel castings, and measures taken to obviate them, are discussed with reference to an example of a wheel casting.

Origin and Mechanism of the Formation of Pinholes and Microporosity. C. A. Sanders. (*Fond. Belge*, 1958, **28**, Jan., 21–23). A summary of a paper presented to the 30th Congress of the Association Technique de Fonderie in Paris, June 1957. The causes of pinholes and microporosity in castings are discussed with particular reference to malleable iron, spheroidal graphite iron, and cast steels.

The Elimination of Porosity in Castings by Means of Inert Gases. (*Fonderia*, 1957, **6**, Jan., 19–21). [In Italian]. Studies carried out in American foundries have established that passing a stream of pure nitrogen through molten iron is a rapid and very economical method of eliminating porosity objects in

castings. It is also shown that blowing argon through steel greatly reduces non-metallic inclusions. The example is given of the use of 150 l of argon/t of 18/8 stainless steel which reduced the H_2 content by half (from 0·0008% to 0·0004%).—M. D. J. B.

Casting Defects Which Do Not Occur Every Day. W. Göschel. (*Giessereitechnik*, 1958, **4**, Feb., 37–40). A description is given of some unusual defects found in castings, with a discussion of their origins.—L. D. H.

Gases in Cast Iron With Special Reference to Pickup of Hydrogen in Sand Moulds. An Account of Recent Work and the Views of British Investigators. J. V. Dawson and L. W. L. Smith. (*Mod. Castings*, 1958, **33**, Feb., 39–52). Data obtained by the British Cast Iron Research Association on the effects of N_2, O_2 and H_2 in cast irons are summarized and detailed results are given of experiments carried out to investigate hydrogen pick-up and pinholing. The effects of Mn, Al and Ti in grey iron, and of Mg, Fe–Si, Al and Ti in nodular iron were studied together with the influence of sand additives and pouring temperature. Al, Mg and Mn all encouraged hydrogen pick-up, but Al appears to be the prime cause of pinholing. The authors conclude that pinholing can be avoided by using ample coal dust and for pitch in the sand, and by avoiding combinations of Al and Ti in the metal.—B. C. W.

Process Charts Applied to Foundry Operations. F. Gaiger. (*Found. Trade J.*, 1958, **104**, Feb. 20, 203–209). The different types of process charts are described and their uses explained.—B. C. W.

Considerations Governing the Purchase of Foundry Materials. C. Dennery. (*Fonderie*, 1957, Aug., 353–362). Purchasing of foundry materials is discussed from the point of view of replacements, new installations, modernization, automation and specilization. It is pointed out that foundries making the same products may well use different methods with advantage.—R. P.

VACUUM METALLURGY

Lines of Development and the Present-Day Importance of Vacuum Techniques. M. V. Ardenne. (*Technik*, 1958, **13**, Apr., 275–285). A comprehensive survey is given of the technical and industrial development and applications of vacuum techniques, with references to the relevant literature.

Vacuum Treatment of Steel in the Soviet Union. A. M. Samarin. (*J. Met.*, 1958, **10**, Mar., 190–192). A review of methods used at three steel plants is presented. Steel is treated in the ladle.

A New Method of Vacuum Treatment of Steel. G. A. Sokolov and G. N. Oiks. (*Metallurg*, 1958, (3), 16–21). A plant at the Red October Works, Stalingrad for degassing in the ladle is described. Steel is poured from one ladle to another in a vacuum chamber and it is also used for vacuum casting of bottom and top poured steel. 12–20 t lots are treated. Diagrams are given.—R. S.

Heat Treating in Vacuum. H. B. Drever. (*Met. Prog.*, 1958, **73**, Mar., 108–109). Furnaces are reviewed and three examples of their uses briefly indicated.

Vacuum Melting Research. (*Iron Steel*, 1958, **31**, Feb., 56). A brief outline is given of the research facilities of Messrs. William Jessop & Sons Ltd., Sheffield. Vacuum melting by two different processes, the consumable electrode process and the vacuum induction furnace, is being studied.—G. F.

The Vacuum Melting of Steel and Alloys for Heavy Ingots. (*Stal'*, 1958, (3), 226). A brief note.

Techniques and Problems in Vacuum Melting. E. A. Loria. (*Blast Furn. Steel Plant*, 1958, **46**, Jan., 73–78). A review is made of the factors underlying vacuum melting and of the results obtained. Arc melting and the effect of pumping rate are considered in detail.—B. G. B.

On the Production of Pure Iron According to the Vacuum-Melting Process. W. Jäniche and H. Beck. (*Tech. Mitt.*, 1957, Dec., 281–294). The paper gives details of the apparatus, tests and results obtained for desulphurizing and deoxidizing electrolytic iron in a vacuum. Desulphurization is achieved by vaporizing the sulphides of tin, antimony or bismuth in a vacuum, the vapours condensing and remaining on the wall of the furnace or crucible. Deoxidation is achieved by means of carbon. (28 references).—R. P.

Consumable-Electrode Vacuum Arc Melting. H. Gruber. (*J. Met.*, 1958, **10**, Mar., 193–198). Furnace design, arc control, vacuum equipment and safety are discussed. The method to be used (air melting, vacuum degassing, induction melting or arc remelting) is evaluated and safety and future possibilities are surveyed.

A Modern Melting Process for the Manufacture of Highest Purity Metals and Alloys. W. Scheibe. (*Metall*, 1957, **11**, Oct., 854–859). Equipment for the consumable electrode vacuum melting process is described in detail.—J. G. W.

REHEATING FURNACES AND SOAKING PITS

The Use of Oil for Heating Soaking Pits in Forging Shops. K. H. Weber. (**Stahl u. Eisen*, 1958, **78**, Jan 23, 87–93). The author describes the conversion from gas-firing to oil or gas + oil for soaking pits, including burner design and placing of the burners. Trials for the vaporization of the oil before combustion were not satisfactory.—T. G.

Insulation of Sliding Tubes in Reheating Furnaces. V. V. Trofimov. (*Metallurg*, 1957, (1), 27–28). The design of chamotte blocks for the insulation of sliding tubes in reheating furnaces is described. It is expected that the introduction of insulating blocks will increase the service life of tubes from 7–7·5 months to 2·5 years.—V. G.

Thermal Insulation of Heating Furnace Slide Tubes. L. A. Tseitlin, A. A. Sorokin, M. F. Filichkin and N. F. Buntman. (*Stal'*, 1958, (3), 262–266).

Comparison of Low-Frequency Induction Heating Installations with Gas or Electric Resistance Heating Furnaces for the Heating of Ferrous and Non-ferrous Metal Billets for Extrusion. J. Putz. (*Metall*, 1958, **12**, Feb., 113–122). Following a description of L.F. induction heating equipment and its operation it is compared with the other types of furnace on the basis of output, heating time, scaling and zinc losses, temperature measurement, manning, space, energy consumption and costs generally.—J. C. W.

Uses of Electric Heating in a Tube Works. E. Hörmann. (*Electrowärme*, 1958, **16**, Mar., 68–71). Arc melting and reheating furnaces, welding installations for containers up to 6 in. dia. and continuous tube welding apparatus are in use, also induction heating.

A Pusher-Type Soaking Pit with Automatic Control and Ceramic Slide Rails. F. Fechter. (**Stahl u. Eisen*, 1958, **78**, Mar. 6, 299–303). The automatic control system of a 2-t capacity pusher-type soaking pit of 10 t/h throughput fired with raw producer gas made from lignite is described.—T. G.

How to Improve the Utilisation and Performance of Large Furnaces in Rolling Mills. F. Vaniš. (*Hutnik*, 1958, **8**, (2), 47–51). [In Czech]. Inadequacies in the use and design of soaking pits are considered, and the effect of suitable remedies are illustrated by means of numerous graphs.—F. F.

Rapid Heating of Steel in Automatic Gas Furnaces. V. F. Kopytov. (*Vestnik Machin.* 1954, (8), 50–51). Construction of furnaces, burners, timing and fuel expenditure, in the preparation of steel blanks for forging, are discussed.—S. I. T.

Construction of a Continuous Furnace With the Use of a Descending Shaft. L. V. Daibel'. (*Metallurg*, 1957, (12), 32). A brief account is given of the construction of foundations and roller tables for a new reheating furnace without disturbing existing foundations or extensive interference with production.—S. E.

The Heating of Steel for Working and Treatment. F. C. Bird. (*Met. Treatment*, 1958, **25**, Jan., 13–21). Electrical methods, conduction and convection processes, fuels and their several uses, especially oil, instrumentation, refractories and furnace design and maintenance are briefly surveyed.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

One Furnace Does Three Jobs. (*Steel*, 1958, Feb. 24, 74–75). A description is given of a specially designed conveyor system permitting one furnace to perform three different heat treatments on a variety of small parts.—A. G.

Effect of Heat-Treatment in a Magnetic Field on the Structure and Mechanical Properties of Steel. H. Jahn. (*Stahl u. Eisen*, 1958, **78**, Feb. 6, 178–180). Steel samples were heated between the poles of a magnet by passage of a current and subjected to a magnetic field at the same time. Air-cooling or waterspray-quenching was employed. D.C. or A.C. of 50 c/s were used for energizing the magnet. Heat-treatment in a magnetic field of 50 c/s and 8000 gauss gave a 25% increase in notch-impact toughness to a 0·05% C steel and, for a higher field strength, 87% to a Cr–Mn steel.—T. G.

Production and Application of Controlled Atmosphere of RX Type. J. Goczal. (*Hutnik*, 1957, **24**, March, 92–99). [In Polish]. The author reviews different kinds of protective atmospheres and their application. The apparatus for production of the RX atmosphere and the method of calculation and regulation of its composition are discussed. Examples of the choice of the atmosphere in the case of chromium steel are given.

Influence of the Size of Grains in Steel 20 KhNM on the Warping and Strength of Motor Gears During Thermal Treatment. N. M. Tarasov and M. R. Semenchenko. (*Metallov. Obra. Met.*, 1955, (1), 53–56). Examination for maximum play of gears due to distortion from their original position showed gaps of 0·11–0·12 mm in components made from fine grained steels and 0·21 mm from coarse grained. It further showed that the strength of component parts made from coarse grained steels was about 20% lower than that of parts made from fine grained material.

Modern Aircraft Steels and Their Heat Treatment. H. Kiessler. (*Schweiz. Arch. Wiss. Techn.*, 1957, **23**, Sept., 304–310). The author discusses the heat treatment of case-hardening, nitriding and corrosion, heat- and acid-resisting steels used for aircraft. Some suitable welding steels are mentioned and the importance of routine testing is emphasized.—R. P.

Heat Treatment of Steels Used in Pressure Casting Dies. K. Schönert. (*Giesserei*, 1958, **45**, Mar. 13, 133–139). A general survey is made of the heat treatment of two alloy steels used in the manufacture of dies, with a note in their hardness testing.—L. D. H.

Special Gas Pipes Used at Lacq. A. Madrelle. (*Corros. et Anticorros.*, 1957, **5**, Nov., 327–330). This paper summarizes methods for the heat-treatment of special drill pipes, casings and tubing which have to withstand high pressures and corrosive soil conditions, the layer of gas being at a depth of 3400–4000 m.

Danelle Process of Hard Surfacing. (*Machinery*, 1958, **92**, May 2, 1023–1024). An oxy-acetylene hard alloy facing method is briefly noted.

More on Sulphinuzation. (*Tecn. Indust.*, 1957, **36**, Nov., 1456–1458). [In Spanish]. Details of the process are given together with notes of its advantages and types of alloy to which it is most suited. Bath composition, action and effect on microstructure are described.—P. S.

Sulphidation of Machine Parts and Tools. P. A. Mishin and Ya. S. Buraya. (*Vestnik Machin.*, 1955, (7), 70–74). Successful application of sulphidation of hardened steel was

made with a view to increasing its resistance to wear. Different sulphur-containing substances were applied at low (170–200° C), intermediate (540–570° C) and high (850–900°) temperature ranges and the most suitable substances and methods were discovered for application to various types of metal objects.

Chromising and Its Industrial Uses. J. Borgnon. (*Usine Nouv.*, 1958, **14**, Mar. 27, 31). A general account of the process and its uses is given.

Two-Stage Case Hardening Reduces Warpage. R. Buyea. (*Metalw. Prod.*, 1958, **102**, Apr. 25, 730–731). A high-temperature dry carbonitriding installation with 2 furnaces working at 1600° F and carburizing for 3½ h with 400 ft³/h generator gas, 25 ft³/h natural gas and 80 ft³/h ammonia, in which the temperature is allowed to equalize for 1 h before quenching is described. Case depth is 0·02 in.

Practical Conditions for Hardening Large Forgings of Structural Steels. A. A. Astaf'ev and K. A. Ermakov. (*Metall. Obra. Met.*, 1956, (4), 35–45). When hardening these large forgings it is advisable to raise quality (elimination of brittleness, increase in mechanical properties, lowering the level of residual stresses after final thermal treatment) to carry out deep cooling during hardening to sufficiently low temperatures. The temperature of the core of the forging at the end of cooling should not exceed 300°. The article considers the duration of hardening in relation to the cross-section of the forging, for cooling under various conditions.—L. H.

High Velocity Gas Stress-Relieving Furnace. E. M. Yard. (*Iron Steel Eng.*, 1958, **35**, Feb., 95–98). A combined convection and radiation furnace has been built to anneal ⅛-in. wire strand in a straight line. Heat from a burner is circulated through the lower heating chamber by a fan. The furnace is 50 ft long, in two sections. It operates at a thermocouple temp. of 850° F, heating rates up to 36 ft/min being achieved. In 75 sec the strand reaches 700° F.—K. E. J.

Distortion and Cracking. F. D. Waterfall. (*Met. Treatment*, 1958, **25**, Mar., 97–100; Apr., 139–144). A review of process in heat treatment leading to these defects is given. Stress production and the effects of the martensite transformation, and tempering and quenching processes are discussed. Effects of case depth, martempering, hardening and grinding are then considered. Examples are given and illustrated.

FORGING, STAMPING, DRAWING, AND PRESSING

The Technique of Forging. O. Kienzle and K. Lange. (*Met. Treatment*, 1958, **25**, Jan., 22–24). An annual review presented to the V.d.I. (47 references).

The Forging of Cylindrical Billets from a High-Speed Steel. I. V. Trush and N. A. Turenko. (*Vestnik Machin.*, 1955, (10), 67–68). Carbide inhomogeneity, especially carbide network, leads to the chipping of high-speed steel cutting tools. Multiple hammering of forged cylinders and rods followed by rolling lead to the improvement of the product.

Influence of Cerium–Lanthanum Additions on the Forging Properties of 18–8 and Higher Alloy Steels. V. Thomas. (*Centre Doc. Sidér. Circ.*, 1957, **4**, (11), 2253–2257). Factors influencing the ductility of this type of steel at forging temperatures and below are discussed particular reference being made to the effect of inclusions.—B. G. B.

Steels For Large Forging Ingots. (*Stahl-Eisen–Werkstoffblatt*, 550–557, 2nd Edn., 1957, Sept., pp. 15).

Die-Steels, Used in Foreign Countries For Drop Forging. A. S. Nikolaev. (*Stal'*, 1958, (2), 162–163).

Forgings and Machinability. G. H. Jackson. (*Met. Treatment*, 1958, **25**, Mar., 91–95). Methods of measurement, defects in steel, inclusions, grain size, composition, heat-treatment, hardness and surface phenomena as related to the machinability of forgings are briefly reviewed.

Metal Flow in Forging (VII). Forging of Steel Balls. T. Awano and M. Ochiai. (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1958, **7**, Mar., 155–163). [In Japanese]. Work with Plasticine is reported and die filling, internal strain distribution, flash prevention, direction of wear in service, use of the bar necking process and the advantages of the rolling method are considered.

Formation of Internal Cracks During Transverse Forging. V. S. Smirnov. (*Vestnik Machin.*, 1955, (3), 49–53). Mechanical processes, arising during forgings, in which the object after each blow is rotated around its axis, are studied in detail and are illustrated by a number of stress diagrams. Functional relationships between critical compression on the one hand and speed of working and temperature on the the other, are discussed. Short periods of deformation and higher temperatures are suggested to prevent the formation of internal cracks.—S. I. T.

The Cold Sinking of Steel. K. E. Thelning. (*Werkstattstekhn. Maschinenbau*, 1958, **48**, Apr., 209–215). Methods are given for obtaining, by formulæ and diagrams, the numerical values of factors likely to influence the manufacture of tools by cold sinking.

Die Stamping and Drop Forging. W. Engelhardt. (*Neue Hütte*, 1958, **3**,, Mar., 165–173). This is a general survey of these processes giving an account of their main characteristics, practical and theoretical aspects of the processes and existing and contemplated measures for their technical improvement.—L. D. H.

"Precision Blanking" of Sheet Metal. (*Sheet Met. Ind.*, 1958, **35**, Apr., 276–278). A process worked out by Heinrich Schmid and the SMG Concern is indicated by which components can be produced with a smooth sheared edge at right-angles to the die face. Characteristics of the presses are tabulated. Deburring is necessary.

Advanced Production Methods in Punching Operations. W. P. Romanowski. (*Neue Hütte*, 1958, **3**, April, 238—246). A general survey is given of modern production methods for components of various dimensions from different semi-finished materials.—L. J. L.

Specialization in the Production of Crane Wheels with a View to Increase of Strength. G. I. Shandrenko. (*Stal'*, 1958, (3), 285–287). Stamping and rolling and standardization is recommended. The service lives for wheels in casting pits, stripper and soaking pit cranes are given. Methods of production and heat-treatment are tabulated. Standard dimensions are also given.—B. S.

The Flanging and Pressing of the Dished Head. H. S. Beers. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 567–589). With many diagrams of presses and presswork.

Technological Aspects of Shaping by Cold Forming of Metals. R. Molle. (*Mét. Constr. Mécan.*, 1957, **89**, Dec., 1021–1027). The author discusses rolling or turning sections, deep drawing and dies of plastic material. Cold-forming depends on the method, the physical structure and the accuracy of the metrological methods.—R. P.

Tips on Spinning Stainless Parts. Allegheny Ludlum Steel Corp. (*Iron Age*, 1958, **181**, Apr. 3, 101–103).

Antifriction Lubricant for the Drawing of Steel Objects. S. A. Valiev. (*Vestnik Machin.*, 1957, (6), 38–39). The use of $Fe(OH)_3$ and iron oxide, together with soap, is recommended. The preparation of the lubricant and the methods of working are described.—S. I. T.

Studies on the Hot-drawing of Steel Tubes. K. Sato and H. Tani. (*Tetsu-to-Hagane*, 1957, **43**, Dec., 1298–1303). [In Japanese]. Investigations were made on the process of hot-reduction of seamless tube through a die, no plug being used. The results relate to the variations of drawing force, drawing stress, reduction rate, outside diameter, wall thickness, and difference between tube and die diameter at various stages in the process.

Experience Obtained in Pushing-in of Steel Rods. W. Pateisky and K. Giesecke. (*Stahl u. Eisen*, 1958, **78**, Mar. 20, 364–367). Long-time trials with pushing-in devices for drawing benches for steel rods show that this process is economical and does not impair the quality of the rods. Operation of the drawing benches has become simpler and less prone to shut-downs.—T. G.

Study of the Surface Phenomena Related to the Wire Drawing of Open Hearth and Electric Steels. M. Vauzelle. (*Mét. Cor. Ind.*, 1957, **32**, July-Aug., 269–285; Sept., 333–342). The results of a comprehensive study of factors affecting the surface properties of steel wires are presented. Studies have been made of the extent of work hardening, the development of prepared orientated structures and the formation of internal tensions. Extensive use has been made of X-ray techniques.—B. G. B.

Martensite-Wire. T. Nishioka. (*Tetsu-to-Hagane*, 1958, **44**, Feb., 151–157). [In Japanese, with summary in German]. An account is given of research into the manufacture and properties of wire made at high speed from low-carbon steel ("martensite-wire"). The wire is heated to 950° C in a protective atmosphere, quenched in 5% NaOH solution and tempered at a temperature above 350° C. Martensite-wire is tough and has a high tensile strength of 100–200 kg/mm²; its properties equal those of wire from high-carbon steel.—K. E. J.

Production of Wire Rope. R. Kristovic. (*Zastita Mat.*, 1957, **5**, Feb., 43–46).

Possibilities and Requirements for the Production and Consumption of Steel Wire Ropes in Yugoslavia. P. Kneževic. (*Zastita Mat.*, 1957, **5**, Feb., 38–42).

Construction, Classification and Properties of Steel Wire Cable. M. Dulic. (*Zastita Mat.*, 1957, **5**, Feb., 52–57).

Elimination of Internal Tension in the Production of Steel Wire Rope. M. Čakmak. (*Zastita Mat.*, 1957, **5**, Feb., 47–51). An account of rope spinning methods.

Determination of the Deformation Rate by Extrusion and Drawing. J. Kocsis and L. Zachár. (*Koh. Lapok*, 1957, **12**, Jan.-Feb., 71–75). A definition of the deformation rate by extrusion and drawing, and formulæ for its determination are given. The influence of various factors on the deformation rate is discussed.—P. K.

ROLLING MILL PRACTICE

The Calculation of the Medial Deformation Resistance during Hot and Cold Rolling. S. Geleji. (*Koh. Lapok*, 1957, **12**, Apr.-May, 145–149). An improved mathematical method is given for calculating the medial deformation resistance during hot and cold rolling, based on the previous publications of the author—P. K.

On the Applicability of the Bach Formula to the Modern Hot Worked Steels. K. A. Kashchenko. (*Vestnik Machin.*, 1955, (3), 75–80). Experiments on various samples of steel showed that there is a marked divergence between the experimental values of relative elongation as calculated by the well-known Bach formula.—S. I. T.

Study of the Effect Produced by Elastic Coupling in the Line of Entry to a Rolling Mill on the Strain Experienced by this Line. B. Blain and J. Stremsdoerfer. (*Centre Doc. Sidér. Circ.*, 1958, (3), 663–666). The question as to whether shock is minimized or increased under these conditions is examined. Cracking apparently due to shock occurred on the reducing train and a rubber cushion was inserted on the outlet side of the roughing mill in front of the reducing rolls. This, however, made the effect worse and cracking became so prevalent as to put the mill out of service. The forces at the line of entry are analysed and a component found which may be responsible for the effect. This was confirmed by filming the movement of the roll and sheet at 1000–3000 frames/sec and the question as to how rigid the system should be is discussed.

On the Hydrodynamic Theory of Hot Rolling. A. Kneschke. (*Arch. Eisenhütt.*, 1958, **29**, Jan., 11–22). The hydrodynamic theory of rolling is presented in an analytical form suitable for use in industry. The functional dependence of mechanical factors on rolling parameters is emphasized.—L. J. L.

Planetary Mill Rolling: Some Practical Aspects. H. W. Ward. (*Iron Steel*, 1958, **31**, Jan., 25–27). The author lists the variables which affect the rolling operation on a planetary mill, and describes and illustrates some of the known effects. Next he considers the advantages of this type of mill and discusses its future, suggesting that it lies in close association with the continuous casting of slabs.—G. F.

Mercury-Arc Converters for Rolling Mills and Mines. English Electric Co. (*Iron Coal Trades Rev.*, 1958, **176**, May 2, 1035–1036). A demonstration for use with reversing drives simulating rolling practice is noted.

Wattless Power Input of Rectifier-Operated Reversing Rolling Mills. H. Nickl. (*Stahl u. Eisen*, 1958, **78**, Feb. 20, 220–226). Wattless power, in particular the wattless power peaks during acceleration and deceleration, of rectifier-operated reversing mills are discussed. Means of reducing wattless power by an improved design of the drive motors are discussed.—T. G.

Relationship between Pressure on the Rolls and Deformation Rate in Rolling. M. Ya. Brovman and R. M. Shpigel'man. (*Stal'*, 1958, (3), 230–235).

How to Improve the Surface State and Rolling Tolerances. M. Thomat. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, **4**, (12), 2441–2447). The importance of ingot heating, draughting and surface state of the rolls on the quality of rolled products is discussed with reference to products other than strip.—B. G. B.

The Manufacture of Steel Mill Rolls. F. Reményi. (*Koh. Lapok*, 1957, **12**, Öntöde, Jan.-Feb., 9–15). The Hungarian manufacture of steel mill rolls from cast iron, melted in an air-furnace, and based on Russian technique and experiences, is described.—P. K.

Study on Charcoal Pig Iron for Chilled Iron Rolls. III. The Relationships between Graphite Precipitation, Gas Exhaustion, Specific Heat and Dilatation of Various Species of Pig Iron during Heating. K. Otani. (*Tetsu-to-Hagane*, 1958, **44**, Feb., 116–121). [In Japanese]. Data are given for gas evolution temperatures, changes of structure on vacuum remelting, specific heat variations and thermal expansion for various charcoal and coke irons.—K. E. J.

The Use, Manufacture, and Heat Treatment of Cast Alloy Steel Rolls. H. Uhlitzsch and G. Radomski. (*Neue Hütte*, 1958, **3**, Jan., 10–20). This, the second part of the paper, deals with constructional materials of rolls as regards their application in rolling mills, and with the heat treatment that can be given to cast steel rolls. The casting of rolls is described; causes of defects and preventive measures are discussed.—L. J. L.

A Study of the Possibilities of Forged Blooming Rolls. M. Massin. (*Rev. Mét.*, 1957, **54**, Sept., 707–719). The results of investigation on 18 blooming trains regarding the wear and fracture phenomena of rolls are reported. Watering appears to be the most important factor affecting wear. Breaking phenomena are associated with rolling practice and roll profile.—B. G. B.

Methods of Use and Possibilities of Increased Life of Rolls. R. Grmela. (*Hutník*, 1958, **8**, (2), 43–46). [In Czech]. Operating factors influencing the life of forged steel rolls of the Cr, Cr–V and Cr–Mo type are discussed. According to Soviet experience electromagnetic and ultrasonic tests may be used to detect faults developing in smaller rolls, and through their timely removal, roll-life may be extended. Instrumentation, i.e. measurement and control of roll pressure, roll surface temperature, etc. can prevent thermal and mechanical overloading.—P. F.

Truck of Special Design Used in Roll Changing. (*Iron Steel Eng.*, 1958, **35**, Feb., 173). Use of a specially designed fork-lift truck releases the busy overhead crane for other work in a large mill.—K. E. J.

Prevention of Pock Marks on Working Rolls. I. M. Meriin. (*Metallurg*, 1958, (3), 24–26). Pock marks in cold mill rolls were eliminated by using rolls with collars half the thickness of the finished strip and by reducing the hardness of the back-up rolls.

Primary Roll Neck Bearings and Their Protection. G. Sackerson. (*Iron Steel Eng.*, 1958, **35**, Feb., 102–108). For good protection, roll necks should be polished, and the grease source should be reliable and checked frequently. Cooling water should be clean, cool and plentiful. Scale guards which form a tight seal are necessary in conditions of heavy scale. Accurate records and programming of work will help to determine the bearing wear allowable to protect the roll neck and maintain predictable bearing wear.—K. E. J.

The Rolling Mills in the Danube Iron and Steel Works. L. Szeless. (*Koh. Lapok*, 1957, **12**, Aug.-Sept., 411–414). The author describes the plan and production scheme of the hot and cold rolling mills in the Danube Iron and Steel Works in Hungary. The width of the broad strip will be up to 1500 mm.

Modern Pilger Mills. Yu. M. Matveev. (*Stal'*, 1958, (2), 151–155).

Prospect and Future Problems of Modern Rolling Techniques. M. Ito. (*Tetsu-to-Hagane*, 1958, **44**, Feb., 109–110). [In Japanese]. — K. E. J.

Modern Trends in the Rolling of Special Steels. N. Cremonese. (*Met. Ital.*, 1957, **40**, Nov., 763–773). [In Italian]. The author discusses the rolling characteristics of special steels with particular reference to the severe limitation of shapes which can be satisfactorily rolled, and to the numerous varieties of steel grades. The increasingly severe market requirements are discussed both in regard to tolerances and surface quality. The most suitable types of plant for rolling these steels are described, heating problems and mill layout are discussed as well as roll pass design.—M. D. J. B.

Time Studies on a Blooming Mill. H. G. Müller and T. Dietrich. (**Stahl u. Eisen*, 1958, **78**, Apr. 3, 397–406). Time studies using automatic oscillographic recording on a 1200-mm blooming mill are described. It is assumed that automatic or semi-automatic control of the mill will save 20–25% of the rolling time for each bloom.—T. G.

Recent Developments in Slabbing Mills. H. J. Kalberkamp. (*Iron Steel Eng.*, 1958, **35**, Feb., 73–80). Details are given of modern installations of universal mills with nominal 45 × 90-in. horizontal rolls and 37 × 96-in. vertical rolls, and of high-lift, 2-high mills which are recommended except in cases where the ultimate possible capacity is needed or slabs over about 60 in. wide are to be produced. Particulars are also given of overhead ingot turning and weighing devices, and of slab shears.—K. E. J.

The Training of Personnel in Wire Rod Mills, with Particular Respect to New Mill Design and Operation. K. Müller-Trimbusch. (*Stahl u. Eisen*, 1958, **78**, Feb. 6, 167–172).—T. G.

MACHINERY AND SERVICES FOR IRON AND STEEL PLANT

Scrap Metal Baling Press. (*Overseas Eng.*, 1958, **31**, Apr., 318). A triple compression hydraulic press for steelworks use is described. Its output is 20-t/hr.

New Ways to Use Electronic Scales. (*Steel*, 1958, **142**, Feb. 17, 124–125). Applications of load cells to steelworks weighing operations are described. Advantages of the method are: ability to work in bad environments and conditions, speed, compactness and convenient transmission of results.—D. L. C. F.

Standardizing Crane Wheels with a View to Increasing Their Strength. G. I. Shandrenko. (*Stal'*, 1958, (3), 285). Crane wheels should be stamped and rolled and should be standardized. Data are given on the lives of Russian and imported overhead crane wheels for casting pit, stripper and soaking pit cranes and on the different methods of producing various types of crane wheels. Standard dimensions are tabulated.—B. S.

Ventilation of the Driver's Cabin on a Stripper Crane. G. I. Ezenkin. (*Metallurg*, 1958, (3), 21). This is a brief note with a diagram describing the ventilation device used at Chelyabinsk. The cranes operate in a surrounding temperature of over 55° C. In summer, the temperature in the cabin reaches 60 to 70° C.—B. S.

Mechanical Maintenance in the Pueblo Plant—The Colorado Fuel and Iron Corporation. J. L. Lindberg. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 487–503). The organization is shown and typical repair and maintenance jobs are illustrated. Mechanical delays per month during 10 years and for March 1957 are given.

The Power Services in the Danube Iron and Steel Works. J. Altnéder and K. Bezdek. (*Koh. Lapok*, 1957, **12**, Aug.-Sept. 343–347). The authors report on the provision of services in the Danube Iron and Steel Works in Hungary, such as steam production, electricity supply, district heating and water supply and the use of top gas and coke-oven gas. They point out the disadvantages arising from the lack of a coke-oven gas holder.—P. K.

Comparison of Gas Turbines and other Engines Applied in Metallurgy. K. Czwiertnia. (*Hutnik*, 1957, **24**, March, 103–111). [In Polish]. The efficiency of gas turbines is compared with that of gas engines, steam turbines and electric motors. The gas turbine is considered to have high efficiency and low capital cost and the author recommends its extended use in the metallurgical industry.

Trends in the Application of Fuel and Heat Efficency Recording and Control Instruments in Iron Works. H. Weineck. (*Stahl u. Eisen*, 1958, **78**, Apr. 17, 494–505). A review of modern instruments and their application in iron and steel works is presented.—T. G.

System of Transport in the Danube Iron and Steel Works. I. Koren. (*Koh. Lapok*, 1957, **12**, Aug.-Sept., 337–343). The system of transport inside the Danube Iron and Steel Works in Hungary, and the outside connections to it, are discussed in detail.—P. K.

Planning of the Handling of Bulk Materials in Iron Works. V. von Branconi and F. W. Griese. (*Stahl u. Eisen*, 1958, **78**, Apr. 17, 465–475). Transport and handling of raw materials in iron works are discussed with reference to the ever increasing quantities to be handled. Means for mechanization and automation of handling plant as well as the economic aspects are dealt with.—T. G.

Simplification and Automation in the Movement of Materials. G. Aimo. (*Fonderia Ital.*, 1958, **7**, Jan., 19–21). [In Italian]. The article describes mechanization and automation at the Ford Motor Works, particularly in the field of materials handling and transport.—M. D. J. B.

Special Road Vehicles for Use in Iron Works. H. Meier-Ebert. (*Stahl u. Eisen*, 1958, **78**, Apr. 17, 491–494). An illustrated review of a number of special road vehicles including one for the transportation of hot blooms in a heat-insulated trailer is given.—T. G.

Calculation of the Net Cost of Steam Raised in Waste-Heat Boilers. I. P. Kropchin. (**Stal'*, 1958, (3), 253–256).

Equipment for Control and Detection of Defects of the Electrical Plant in Iron Works. K. Stahl. (*Stahl u. Eisen*, 1958, **78**, Jan. 23, 94–100). Modern instruments, transportable or built in at a central testing station, are described and a number of examples for their use cited.—T. G.

On the Treatment of Waste Waters in the Metallurgical Industry. E. Zamrzla. (*Hutn. Listy*, 1958, **13**, (2), 133–141). [In Czech]. Water supply and regeneration at all stages of the iron and steelmaking process, as well as in pickling plant, are discussed. Separate canalisation of water from different sources, closed circuit water supplies including regeneration stages, and the cooperation of the chemists to solve particular problems are advocated. Specific cases are considered.—P. F.

WELDING AND FLAME-CUTTING

Welding Science in Great Britain. N. N. Rykalin and M. Kh. Shorshorov. (*Izvest. Akad. Nauk, Otdel. Tekhn.*, 1957, (10), 61–67). The authors give their impression of welding research and techniques in the U.K. as

gathered during a visit in Oct.-Nov. 1956 and describe some of the outstanding work.—S. K.

Vertical Welding Without Preparation. A. J. v. d. Velde. (*Lastechn.*, 1958, **24**, Feb., 17–19). [In Dutch]. The author describes a vertical method of welding materials without the need for previous machining and which has been long in use at the Pernis Shell Plant. Two welders work in relays as the electrodes become used up, holding the latter in a downwards direction and working upwards until near the top when one welder finishes off the job. The method gives satisfactory results and the article concludes with particulars of macroscopic examinations and of mechanical (tensile, bending, notched bar impact) tests. Several illustrations of etched welds made by the method described appear in the text.—F. R. H.

Tungsten Inert Gas Welding of Spheroidal Graphite Cast Iron. J. Ruge and W. Zitzelsberger. (*Schweissen Schneiden*, 1958, **10**, Mar., 86–90). Investigations are described into the Argonare welding of ferritic nodular cast iron. Preheating to at least 350° C is necessary for crack-free welding; if this temperature is 600° C, the seam can be made ferritic almost to the surface, the last layer being ledeburitic. There are disadvantages in a two-stage heat treatment to remove carbide completely. Monel metal was added in an attempt to produce a soft surface layer, but nickel martensite was formed in the transitional zone.—L. D. H.

Inert-Gas Tungsten-Arc Welding SAE 4130 Steel Sheet—4. C. A. Terry and W. T. Tyler. (*Weld. Met. Fab.*, 1958, **26**, Feb , 58–61). A study of factors influencing hot cracking is reported. Direct relationship to S and C content was found, but the most severe effect arises from banded ferrite–pearlite microstructure. All tests were made on sheets with a C-rich surface layer so that results on C content are uncertain but cracking seems to occur at or near solidus temperature.

Welding Stainless Steel. B. Mulder. (*Lastechn.*, 1958, **24**, Apr., 51–57). This article begins with a lengthy discussion on the tendency of steels to rust with particular reference to stainless steels. It then goes on to deal with the welding characteristics of eight AISI Rs types of stainless steels. The questions of oxidation and chemical change during welding are considered. The practical problems arising during welding operations are discussed and methods of preparing the material for welding, also the tools needed for subsequent finishing. (straightening buffing and grinding) of the welds and the precautions to be observed, receive attention.—F. R. H.

Electric Welding of Stainless Steels. (*Tecn. Indust.*, 1957, **35**, Dec., 1609–1610). [In Spanish]. A brief outline is given of the special problems encountered in the electrical resistance welding of stainless steels. These include the comparatively high electrical resistance of these steels and the need for high-speed welding to inhibit the separation of carbides.—L. D. H.

Arc Welding of Stainless Steels by a Fusion Electrode in Inert Gas Media. A. V. Petrov. (*Vestnik Machin.*, 1954, (9), 68–70). Details are given of most successful trials of arc welding with the use of a fusion electrode in an atmosphere of He and A.—S. I. T.

The Causes of Flaws in Welded Joints of Small Diameter Tubes. V. M. Kondrat'ev and G. L. Petrov. (*Vestnik Machin.*, 1954, (6), 78–83). [In Russian]. Experiments were carried out in testing welded joints of the steel pipes of economizers and water heaters for high pressures. A carefully studied process of welding suggests the adoption of a special scheme which would prevent the corrosion of welded joints from the action of flowing hot water.—S. I. T.

The Influence of Manganese on the Segregation of Sulphur in Welded Seams of Carbon Steels. L. A. Poznyak. (*Avtom. Svarka*, 1958, **11**, (1), 80–86). An increase in Mn content to 2–2½% in low-carbon steels (0·10–0·11% C) does not change the segregation of sulphur, but in medium carbon steels, when segregation of sulphur attains 150–160%, an increase in Mn gives rise to a reduction in segregation. It was established in micro X-ray tests that a Mn content above 1·5% in the weld causes chemical non-uniformity in boundaries of the crystal particles, which reduces the impact viscosity of the weld metal.—L. H.

Cracking Due to Welding in the Transformation Zone of Air-Hardening Alloy Steels. H. Sekiguchi and T. Kobayashi. (*Rev. Soudure*, 1958, **14**, (1), 51–58). Four types of crack were distinguished as a result of welding Ni–Cr–Mo air-hardening steel, and the origin of each is discussed. In certain cases, preheating and the use of an austenitic type of electrode are useful in preventing cracking.

Welding Cracks in the Heat-Affected Zone of Air-Hardening Alloy Steels. H. Sekiguchi and T. Kobayashi. (*Soud. Techn. Connexes*, 1957, **11**, Nov.-Dec., 397–403). The authors give results of tests made by depositing an arc-welded bead on an air-hardening alloy steel, using various types of electrodes. The inert gas-shielded arc technique is used as an alternative. Austenitic electrodes give the best results. Pre-heating and post-heating reduce the risk of cracking.—R. P.

The Appearance of Surface Cracks During the Brazing of Steel. R. Tidlund. (*Soud. Techn. Connex.*, 1958, **12**, Jan.-Feb., 69–75). A series of experiments are described in which the cause of cracks during the brazing of steel was investigated. It was concluded that the cracking was attributable to intergranular penetration by the brazing alloy. The evidence given is supported by photomicrographs.—L. D. H.

[Cracking of Austenitic Cr–Ni–Nb Weld Metal]. E. Bishop and B. I. Medovar. (*Weld. Met. Fab.*, 1958, **26**, Feb., 72). Correspondence is published on the subject in which the mechanism of formation of weld micro-cracks is discussed.

Soldering with Heat-Resisting Solders. V. A. Gorokhov and M. I. Skripov. (*Vestnik Machin.*, 1955, (7), 47–51). Solders compound of Cu, Ni and Mn (1040–1100° C), Si, Be, Zn and Fe (960°–1000° C) or Cr (1200–1225) were tested in soldering steel to an alloy. Macro- and microstructures of joints were studied by means of metallographic analysis, and intercrystalline corrosion was also studied, as well as heat-resistance and metal fatigue and certain conclusions are drawn.

Brazing Salvages Cracked Stampings. E. H. Conway. (*Steel*, 1958, **142**, Mar. 3, 110, 112, 114–115). Steel stampings are repaired by peening the crack to widen it and using a flame fluxing process and a nickel silver filler.

The Repair of Iron Castings by Brazing. (*Fonderia*, 1957, **6**, Jan., 25–26). [In Italian]. The technique of repairing iron castings by means of brazing is described. It is claimed that the method has great possibilities for repairs to parts ½ in. thick and upwards.

Progressive Process of Brazing in Salt Baths. P. T. Gorodnov and I. M. Korotin. (*Vestnik Machin.*, 1955, (9), 50–53). Experiments were made on brazing machine parts in a salt bath ($BaCl_2$ and NaCl) by means of copper brazing alloy at 1135–1140° C during 2–3 min. Clean surfaces of metal and purity of salt are essential. The results of tests of finished products are given.—S. I. T.

The Nature of High Temperature Brazing Alloy-Base Metal Interface Reactions. W. Feduska. (*Weld. J.*, 1958, **37**, Feb., 62s–73s). Wettability tests were carried out with martensitic and austenitic stainless iron base, nickel base and cobalt base alloys. Microstructures have been reproduced showing the brazed-joint interfaces.—U. E.

Fatigue Strength of Silver-Alloy Brazed Joints in Steel. C. H. Chatfield and S. Tour. (*Weld. J.*, 1958, **37**, Jan., 37s–40s). Laboratory tests on SAE 1020 and SAE 4140 steels brazed with an oxy-acetylene torch and an alloy conforming to AWS A5·8–52T specification BAg-1. The strength was ~ 22,500 p.s.i. independent of the steel where the joints were free from surface defects.

Filler Metal Comparison Charts—AWS A 50–57. (*Weld. J.*, 1958, **37**, Feb., 128–135). Manufacturers' names and addresses are listed and tentative specifications for brazing filler metals, covered and bare stainless steel electrodes, high-tensile and low-alloy steel, mild steel, and iron and steel electrodes, also light metal, copper and nickel electrodes.

Dual Fixturing Boosts Brazing Rate. W. E. Atkinson. (*Iron Age*, 1958, **181**, Feb. 6, 100–101). The technique of brazing bicycle frames at Evans Products Co., Mich. is described. It was found that by providing a second fixture to be loaded while brazing was in progress in the other, output was considerably increased.—D. L. C. F.

Adhesives for Metals. A. E. Williams. (*Iron Steel*, 1958, **31**, Jan., 11–14). There is now quite a number of metal adhesives available, the selection of any one depending on the nature of the particular job and its ultimate function. The author outlines their advantages and disadvantages when compared with the more usual methods of metal jointing, and discusses the factors affecting the design of the joint and the bond strength. A particular example described is the bonding of steel and other metals to ceramics.—G. F.

Ceramic Structural Adhesives. H. G. Lefort, R. M. Spriggs and D. G. Bennett. (*Machine Design*, 1957, **29**, Oct. 31, 114 from *WADC Techn. Rep.*, 55–491, (2), *PB* 121941). Bonding materials for stainless steels with shear strengths of 1200 psi at room temp., 1100 psi at 600° F, 1500 psi at 800° F, 2300 psi at 900° F and 800 psi at 1000° F are developed.

New High-Temperature Structural Adhesive. H. H. Levine. (114–115; from *WADC Techn. Rep.*, 55–271, (2), PB 121908). An inorganic material is mentioned interacting with steel surfaces. Primers have positive or negative effects according to composition.

Gas Cutting of A52 Steels. W. Soete and E. Sellier. (*Rev. Soudure*, 1957, **13**, (4), 219–226). Results are given of an investigation into the effects of oxyacetylene flame-cutting on the properties of A52 steels (0·20%C, 1·5%Mn). Microhardness measurements showed that the hardness fell from 659 to 300 Vickers within 0·1 mm of the cut face, and to the value for the untreated steel, about 200 Vickers, within about 1·2 mm. The ductility of the steel at the cut face was considerably less than that of the untreated metal but was increased by pre-heating or post-heating.—B. C. W.

The Application of Oxygen Cutting in Foundries and Steelworks. O. Grossi. (*Fonderia*, 1958, **7**, Apr., 143–151). The author reviews present applications of oxygen cutting in foundries and steelworks and suggests that these will increase steadily. Practical examples of installations are described and technical data are given. [7 references.]—M. D. J. B.

The Arcair Torch. A Production Aid in the Steel Foundry. T. D. Warren. (*Weld. Met. Fab.*, 1958, **26**, Feb., 67–70). An arc with two air jets to remove melted metal is used for the removal of gates, risers, fins, defective areas and other minor faults.

MACHINING AND MACHINABILITY

Machinability of Metals. H. Takeyama and E. Usui. (*J. Mech. Lab.*, 1957, **3**, (2), 81–86). Chip formation is examined for correlations with physical properties. The importance of contact area is confirmed. Cast irons, steels and non-ferrous metals are compared.

Metallurgy and the Machinability of Steels. F. Grandi and A. Masi. (*Ing. Mecc.*, 1957, **6**, Nov., 17–24). [In Italian]. After a brief review of the various machinability tests in current use in industry, the authors discuss the relationship between the metallurgical properties of steels and their machinability characteristics; the effects of hardness, tensile properties, structure and composition are studied. Sulphurized steels are examined and their properties are discussed. In the field of free-cutting steels, special mention is made of leaded steels as a means of improving the machinability of low-carbon, high-nickel carburizing steels for gears. The possibility of using leaded steels for high-resistant grades is also examined.—M. D. J. B.

Tool Steels in Service: I. Theoretical Considerations; II. Practical Aspects. A. P. T. Taylor-Gill. (*Iron Steel*, 1957, **30**, Dec., 631–635; 1958, **31**, Jan., 19–24). This article is designed to assist the user of tool steels to obtain practical benefit from the ability of the physical metallurgist to define structures and to suggest treatment techniques to reproduce them. The author discusses the structures desired for different service conditions, and describes suitable heat treatment practices. Methods for reducing size change due to distortion, and controlling size change associated with structure and composition, are also discussed.—G. F.

A Guide to Tool Steels and Carbides. (*Steel*, 1958, April 21, S1–S44). For the convenience of buyers of tool steels, carbides and ceramic materials, a cross-indexed list is given of materials (over 1100) and sources (over 70 companies).—A. G.

Ceramic Cutting Tools. (*Mech. World*, 1958, **138**, May, 210–211). A brief discussion of properties and uses.

Plastics in the Toolroom. (*Steel*, 1958, **142**, Feb. 3, 108–111). Particular attention is given to epoxy resins in this survey of the applications of plastics for dies and formers.

Increasing Productivity in the Planing of Heat Resisting Alloys. A. V. Pakhomov and L. A. Rozhdestvenskii. (*Stal'*, 1958, (3), 241–242). A study was made of the strength, geometry and quality of cutting tools. Design of tool is illustrated. Details of the planing procedure are given. The method described leads to an improvement in cutting efficiency, resistance to vibration and efficient removal of chips. Productivity of the planing machine was increased by 15 to 20%.—R. S.

Machining and Grinding of Nodular Cast Iron. (*Mét. Constr. Mécan.*, 1958, **90**, Apr., 273–283). This is a general survey of the techniques used in machining and grinding spheroidal graphite cast iron, giving details of tool materials, cutting speeds, grinding and lapping and heat treatments, with illustrative examples.

The Working of Hardened Alloy Steels by Cutters with Ceramic Tips. V. I. Zhikharev. (*Vestnik Machin.*, 1955, (7), 35–37). Experiments were made on the wear of ceramic tips used in cutters for working steels of 50–59 R_C hardness. The following factors were studied: cutting angle, rake angle, radius at the top of the cutter and rate of feed. Mathematical relations and graphs are given.

Vibration Detectors Cure Mysterious Machining Ills. (*Iron Age*, 1958, **181**, Feb. 6, 98–99). Vibration-detecting instruments are described and examples given of their application. The instruments may use sensitive transducers. They are useful for finding the source of trouble in machining operations.—D. L. C. P.

Metallography Solves a Tough Machining Problem. A. J. Belli. (*Iron Age*, 1958, **181**, Feb. 20, 96–98). The step-by-step report describes how the problem of drilling tough valve guide castings was solved. Heats of the 27%Cr ,2·5%C alloy differed in machinability. Hardness and metallographic examination enabled the good and bad heats to be identified. A partly dendritic structure gave better machining than a closely-packed carbide structure.—D. L. C. P.

Thread Cutting on Tubes with Round Tapping Dies. I. A. Gurin. (*Metallurg*, 1957, (12), 31). Data on the service life of round dies used for threading the ends of 8– and 10–12 in. diameter tubes are given. Soviet-made dies are said to have proved superior to imported ones.—S. K.

On Structure Transformation in Metal Chips Removed in High-Speed Cutting. E. I. Feldshtein. (*Metallov. Obra. Met.*, 1955, (1), 51–53). Investigations have shown that under conditions described, no phase transformation can be detected in the layers removed, and that the cementite particles keep their original form and dimensions.—L. H.

Temperature Fields Appearing in Chips Under the Influence of the Front Edge of the Cutting Tool. A. N. Reznikov. (*Zhur. Tekhn. Fiz.*, 1958, **28**, (1), 207–217). An increase in the thickness of the cutting tool lowers slightly the temperature gradient and extends the field in chips where heat is spreading. An increase in the cutting speed reduces this field in the chips but its distribution in depth depends on the cutting angle.—L. H.

The Relation Between the Stability of the Disc and the Regime of Grinding. E. N. Maslov and B. A. Ignatov. (*Vestnik Machin.*, 1954, (6), 50–54). [In Russian]. The stability of grinding discs for grinding steel depends on longitudinal feed, transverse feed, velocity of rotation and diameter of the disc. To a lesser degree it depends on the diameter of the worked object, hardness and granularity of the disc and composition of the cooling fluid. Formulæ, graphs and nomograms relating to this subject are given.—S. I. T.

Study of Precision and Finish of Surfaces on Working of Cast Iron with Carbide-tipped Boring Tools. A. D. Trubenok. (*Vestnik Machin.*, 1957, (6), 50–53). Various graphs and empirical formulæ are given, and optimum values for feed, angles, depth of cutting, and other factors, are suggested.—S. I. T.

Deburring with Ultra Sound. (*Steel*, 1958, April 7, 102–103). The process of ultrasonic deburring is briefly described. Its main application is for the removal of small burrs from close tolerance parts.—A. G.

The Selection of Cooling-Lubricating Liquids for the Finishing Treatment of Deep Holes in Austenitic Steel. G. S. Andreev. (*Vestnik Machin.*, 1954, (11), 39–42). A detailed account is given of experiments carried out with different cooling-lubricating liquids in the drilling and grinding of steel.—S. I. T.

On Electro-Erosive Metal Treatment. O. Rüdiger and A. Winkelmann. (*Metall*, 1958, **12**, March, 366–380). The term "electro-erosion" is applied to all processes in which material transfer is effected by electrical discharges between to electrodes in a liquid. There is no mechanical interaction between material and tool. Electro-erosion drilling techniques are described in detail.—L. J. L.

Spark Machining of Forging Dies. R. Chevallier. (*Met. Treatment*, 1958, **25**, Apr., 135–138, 144). A review of the development of the process and equipment.

CLEANING AND PICKLING

The Degreasing of Metals. L. Mauri. (*Acero Energ.*, 1957, **14**, Nov.-Dec., 52–58). [In Spanish]. The various techniques of degreasing are reviewed and details of the methods, machines and chemicals used are given together with recommended formulæ for special cases.—F. S.

Get Parts Cleaner by Ultrasonics. N. G. Branson. (*Mat. Design Eng.*, 1958, **47**, Feb., 118–121). A review, including non-metallic uses.

Strip Descaled Automatically. (*Steel*, 1958, **142**, Mar. 10, 136). An account of the shot-blasting descaler of Midland-Ross Corp., Cleveland (Ohio).

Preliminary Investigation on Cleaning by Blasting of Steel Structures. J. H. Zaat. (*Metalen*, 1958, **13**, Feb. 26, 62–70; Mar. 15, 81–88). [In Dutch]. The paper gives the results of a microscopical examination of the surfaces of steel plates after subjection to blasting with zirconium sand, sand, cast iron grit, cut steel wire, corundum, and emery. The results obtained are shewn in tabular form in conjunction with numerous micrographs illustrating the condition of the surfaces after treatment. Results are then given of the preliminary investigation on the cleaning of steel structures using eight types of blasting media. Cut wire proved itself to be the most suitable for the particular purpose in view although it is pointed out that the findings do not necessarily apply to structures made of other materials, e.g. cast iron, non-ferrous metals, etc. Cut wire is deemed easy to use, rapid in action, dustless, easily cleaned, and more durable, it does not break up or become embedded superficially thus avoiding possible sources of corrosion and like troubles. Further work is recommended. Numerous illustrations of the various blasting media examined before and after test appear in the text.—F. B. H.

The Application of Shot-Descaling to Rod Drawing. F. Kottmeier. (*Stahl u. Eisen*, 1958, **78**, Mar. 20, 358–364). Design and mode of operation of a shot descaling plant for rod are described and service life of the plant discussed. Surface defects of the rods descaled by this method are easier to detect than of rods chemically descaled.—T. G.

The Removability of Scale from Steel Sheet. W. Rädeker and M. Wild. (*Stahl u. Eisen*, 1958, **78**, Jan, 23, 100–103). Rimming steel or steel killed with Si or Si + Al were poured at various temperatures and rolled at 650°–1050° C. The removability of the scale was determined by pickling, sand blasting, flame cleaning and weathering. The results of the study are described in detail.—T. G.

High Frequency Vibrations Slash Barrel Finishing Time. (*Iron Age*, 1958, **181**, Feb. 20, 86–87). The 'Vibraslide' barrel finishing machine is described. The barrel, in addition to the normal rotation at 4 to 20 r.p.m., can be vibrated endways 2300 times per min. Advantages include considerable reduction in finishing times, increased loads, avoidance of need for racks, possibility of treating difficult shapes. The vibrating action may be used alone for long or delicate parts.—D. L. C. P.

The Application of Oxy-Acetylene Flame Cleaning to the Preparation of Rolled Products for Spot Welding. Evrard. (*Rev. Soudure*, 1957, **13**, (4), 195–210). The adverse effects of surface scale on the contact resistance and wear of electrodes used to spot weld steels are illustrated, together with the effects of scale on the quality of the weld. A descaling technique using an oxyacetylene flame followed by a water jet is described in detail, and the results of an extensive investigation into the influence of various operating factors on the efficiency of the descaling procedure are presented. In conclusion torsion test data are given for welds made under identical conditions between sheets which had been descaled by five different techniques. The best results were obtained with the flame descaling process.—B. C. W.

Metal Polishing Developments. D. J. Fishlock. (*Mech. World*, 1958, **138**, Mar., 102–106; Apr., 180–184). A review of techniques for ferrous and non-ferrous metals including barelling and Roto-finish methods, blast cleaning and barrel polishing and solution polishing are outlined.

Steel Pickling: When Should It be Used? (*Western Metalw.*, 1958, **16**, Mar., 58, 60). Hot-rolled pickled steel is reviewed, especially for plating, and the operations of various firms are indicated.

The Effect of Rolling Conditions on the Properties of Hot Rolled Low-Carbon Steel Strip. I. Structure of the Scale and Its Behaviour in Pickling Baths. W. Dahl and W. Lueg. (*Stahl u. Eisen*, 1958, **78**, Mar. 20, 368–377). An apparatus is described for the continuous recording of weight loss, potential and current density of steel samples in a pickling bath. It was found that the scale of commercially produced hot strip steel has not a uniform structure and composition, it consists of wüstite, magnetite and hematite layers of varying thicknesses. The thickness of the scale increases with increase in rolling temperature and is proportional to the time the strip is exposed to the atmosphere at temperature.—T. G.

Cast Stainless Stands Up to Pickle Liquor. (*Steel*, 1958, April 14, 141). To resist the solutions used in the pickling and cleaning of stainless steel wire and strip, the use of type CN–7M stainless alloy is briefly advocated.

PROTECTIVE COATINGS

Science for Electroplaters. L. Serota. **25–27. Waste Disposal.** (*Metal Finishing*, 1957, **55**, June, 88–90; July, 58–60; Aug., 69–71). A review of the effects, economic and legal aspects and treatment of effluents is given and recovery is then outlined. Treatment of acid wastes, pickle liquors and the air oxidation process are outlined. **28. Treatment of Chromate Wastes.** (Sept., 65–67, 71). Precipitation processes and reduction

treatments are outlined, using sulphide, SO_2 or ferrous sulphate, and the ion-exchange method is then considered. Materials used and sludges formed are summarized. **29. Cyanide Disposal Methods.** (Oct., 75–77, 79). A table of the concentrations encountered and dilution methods, complex formation, ponding, and the lime-sulphur method are given. **30. Acidification of Cyanide Waste.** (Nov., 72–75). Treatment with H_2SO_3 and the effects of temperature, pH and aeration on cyanide removal are discussed. **31. Chlorination.** (Dec., 77–80). The chemical principles underlying the oxidation by Cl_2 are given and batch processes are described. **32. Hypochlorites.** (1958, **56**, Jan., 61–64, 67). Tests on cyanide effluents with NaOCl are quoted and conditions of oxidation and cyanogen chloride formation discussed. Cyanate formation and removal is reviewed. **33. Ozonation and Electrolysis.** (Feb., 71–74). A review of published trials. $KMnO_4$ is also reviewed. **34. Cyanide Removal by Ion Exchange.** (Mar., 72–75). Trials on Zn and Cu plating solutions are noted. **35. Ion Exchange Properties.** (Apr., 68–70).

Procedures for Coating Metals. L. Krošar. (*Zastita Mat.*, 1956, **4**, July, 236–238, 242). Cladding is discussed, also coating by sintering.

Protection of Structural Steelwork in Chemical Plant. M. Waghorn. (*Corros. Techn.*, 1958, **5**, April, 103–106). The author discusses the three most important steps towards the successful protection of any metallic surface, namely: 1. surface preparation; 2. surface cleaning and 3. choice of coating. The factors governing the choice of method of preparing the surface are given and the main methods are briefly described. The necessity of cleaning the surface in order to prevent the spreading of contaminants is pointed out. The choice of coating is considered in some detail and suitable coatings are enumerated for use where: 1. the coating is subjected to continual and direct contact with the corrosive; 2. there is a high concentration of corrosive fumes, frequent splash and spillage; 3. there is a relatively high concentration of fumes but no splash, spillage or direct contact with solid or liquid corrosive, and 4. there is a mild concentration of fumes and resistance to weathering is required.—L. E. W.

Metallic Coatings for Corrosion Prevention. C. L. Faust and W. H. Safranek. (*Mat. Design Eng.*, 1958, **47**, Feb., 147, 149). A tabulated summary of metals and alloys and their uses.

Corrosion Protection by means of Electrodeposited Metallic Coatings. J. Elze. (*Metall*, 1958, **12**, Jan., 32–38). Following a general discussion of the chemical behaviour of the coating-base system and of coating thickness, the characteristics and uses are described of coatings of various metals and alloys that can be electro-deposited.—J. G. W.

Waste Water from Industrial Electroplating. K. Volz. (*Metalloberfläche*, 1958, **12**, Jan., 1–4). The nature and level of concentration of the impurities found in waste water from the various stages of commercial electroplating are discussed, in relation to their effect on marine life.—L. D. H.

Ion Exchangers in the Treatment of Waste Water. A. Von Krusenstjern. (*Metalloberfläche*, 1958, **12**, Jan., 4–5). A general description is given of the use of ion exchangers in the treatment of waste water, with reference to the literature. (26 references).—L. D. H.

Calculation of Costs for the Construction and Operation of Waste-Water Plants According to the DEGUSSA Process. E. Asendorf. (*Metalloberfläche*, 1958, **12**, Jan., 6–8). A calculation of capital outlay and operating costs shows that the DEGUSSA plant for the treatment of waste water is capable of significant economies compared with less modern installations.

Permissible Detoxication and Neutralisation of Waste Water. K. H. Hartung. (*Metalloberfläche*, 1958, **12**, Jan., 17–21). After outlining the required degree of waste-water discharged from electroplating plants, a summary is given of equipment for measuring, regulating and treating the water and its constituents. (14 references).—L. D. H.

A Plant for Detoxicating Waste-Water from Electroplating Installations. P. Douwenga. (*Metalloberfläche*, 1958, **12**, Jan., 22–26). The construction and operation of a waste-water purifying plant in connection with the electroplating equipment at the Ford works at Köln-Niehl are described.—L. D. H.

The Testing and Examination of Electrodeposits. 5. Porosity Tests. R. Quarendon. (*Prod. Fin.*, 1957, **10**, Nov., 70–82, 122). The mechanism of formation and the chemical and other effects of pores, the ferrocyanide test and its modifications, salt spray, electrographic and hot water tests, tests for anodic deposits and the immersion, gas and vapour exposure, Dubpernell and gas permeability tests are outlined and the more important are discussed. (56 references).

A Radiometric Study of the Iron Phosphating Process. S. L. Eisler and J. Doss. (*Ind. Fin.* 1957, **9**, Dec., 1008–1012). Spray and immersion methods of application were used to compare iron phosphate with Zn and Mn phosphate coating processes using radio-phosphoric acid. The coatings varied from batch to batch of solution and only relatively small amounts of iron phosphate were formed. Where corrosion resistance is important the iron phosphate process is unsuitable but as an undercoating for phenolic varnishes requiring a high baking temperature it may be recommended.—A. D. H.

'Bitugel'—New Anti-corrosive Bitumen Composition. E. A. Duligal. (*Corros. Techn.*, 1958, **5**, May, 152–155). The author defines bitumen and indicates the advantages and limitations of bitumen in paints. The development of 'Bitugel' is then traced and its properties are evaluated. The method of application of 'Bitugel' is described and possible uses are considered.—L. E. W.

Protective Organic Coatings for Steel. L. J. Nowacki and E. R. Mueller. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 271–283). A review, including pre-treatment and application.

The Protection of Metals by Means of Latex Coatings. L. Mitrovic. (*Zastita Mat.*, 1957, **5**, Aug., 300–303).

V.C.I. Protection of Iron and Steel. Some Practical Results. L. Lund. (*Tekn. Uke.*, 1958, **105**, May, 393–394). [In English]. Laboratory tests and service trials have shown that the volatile corrosion inhibitor *cyclo*hexylamine carbonate prevented corrosion of compressor vanes in turbo-jet aero engines of the axial flow type.

Epoxide Resins in Anti-Corrosion Finishes. F. L. Farr. (*Ind. Fin.*, 1957, **9**, Dec., 986–991). Applications of epoxide resin paints are described. The coating is tough, flexible and chemically inert.—A. D. H.

Epoxide Resins Versus Corrosion. L. M. Barakan and G. L. E. Wild. (*Corros. Techn.*, 1958, **5**, May, 137–140). The authors discuss the relative merits and methods of application of the four main groups of epoxide resins, which are: (1) resin-containing coatings, based on epoxide esters, which dry at ordinary temperature by oxygen absorption; (2) cold-setting or catalysed coatings which harden at ordinary temperature through chemical reaction; (3) stoving epoxide coatings which can be stove-hardened at 250° to 300° F. In this class the epoxide resin medium is modified with conventional paint media, and (4) stoving epoxide coatings which are hardened at 350° to 500° F.—L. E. W.

Epoxy Resins in Corrosion-Resistant Applications. P. A. Dunn. (*Corros. Techn.*, 1958, **5**, May, 143–147). The author discusses briefly the chemistry of epoxy resins and lists their properties. The applications and limitations of casting resins, laminating resins and surface coating resins are dealt with, air drying finishes are considered and the use of epoxy resins as fillers is referred to.—L. E. W.

'Hypalon' Coatings. H. J. Lanning. (*Corros. Techn.*, 1958, **5**, April, 110–114). The author discusses the properties, chemical composition, vulcanization and curing of 'Hypalon' and describes the methods of preparing and applying 'Hypalon' linings. 'Hypalon' is a chlorosulphonated polyethylene and the reason for the inclusion of sulphonyl chloride groups is to provide sites of reactivity through which vulcanization can be effected and thus to ensure elasticity. In 'Hypalon' coatings which at present are regarded as conventional there are three groups of essential ingredients: a metal oxide, a weak organic acid and an accelerator. The function of each constituent and the quantity necessary for the best results are specified.

'Neoprene' and 'Hypalon' for Chemical Plant Linings. C. H. J. Avons. (*Corros. Techn.*, 1958, **5**, April, 107–109). The author describes the properties of 'Neoprene' and 'Hypalon,' discusses their applications and indicates the precautions to be observed. 'Neoprene' possesses advantages over natural rubber for use with oils and hydrocarbon solvents, heat, oxygen and for resistance to sunlight. Like rubber it should not be used in contact with high swelling liquids such as aromatic and chlorinated hydrocarbon solvents. 'Neoprene' compounds based on zinc oxide and magnesium oxide vulcanizing are not recommended for chemical plant owing to their high water absorption. Compounds based on litharge or red lead vulcanizing absorb much less water but must not be used where foodstuffs are involved. 'Hypalon' possesses the chemical resistant properties of polythene whilst enabling vulcanization to be achieved by the introduction of reactive sites in the molecule through which cross linking can be effected. 'Hypalon' is resistant to ozone, weathering and heat (possibly up to 300° F) and has greater resistance than rubber to strong oxidizing chemicals.—L. E. W.

Some Synthetic Elastomers Used as Corrosion Protectors. E. S. Voutetakis. (*Corros. et Anticorros.*, 1957, **5**, Sept., 244–252). The uses of elastomer coatings as corrosion protectors are discussed. Methods of application and resistance to attack by various chemicals are given. The relation between solvent and viscosity is dealt with.—R. P.

Control of Colour. H. A. Morriss. (*Ceramics*, 1958, **9**, Apr., 16–20). An account of colour control in enamels. General indications of composition with some details of kiln operation, temperature measurement and testing are given.

Hydrogen Treating Process for Steel. J. H. Healy and J. D. Sullivan. (*J. Am. Ceram. Soc.*, 1958, **41**, Apr., 141–145). The process improves enamelling properties. A study is reported in which exposure to cathodic hydrogen produced a decrease in density and an increase in porosity and the material was examined by ultrasonics. On removal of the hydrogen glass can be applied free from high and low temperature hydrogen defects and various other advantages are claimed.

The Solubility of Ferric Oxide in Enamel Coatings for Steels. K. P. Azarov and V. V. Balandina. (*Zhur. Priklad. Khim.*, 1958, **31**, (2), 308–309). The solubility of ferric oxide in enamel coatings is determined at 850° and 950° C by measurements of the refractive index.

Protection of Steel by Painting Against Atmospheric Corrosion. J. C. Hudson. (*Schweiz. Arch. Wiss. Techn.*, 1958, **24**, Feb., 46–56). The author discusses results of work carried out by B.I.S.R.A. The most important factor is efficient surface preparation, blasting and pickling being recommended for descaling and derusting. Design of structure, choice of priming and finishing paint as well as the method of application should be considered carefully. The composition of a steel is not the main factor in determining a painting scheme but may determine the intervals between repaintings. (19 references).—R. P.

Constructional Design to Facilitate Painting and Corrosion Protection. K. A. van Oeteren. (*Werks. Korr.*, 1958, **9**, April, 197–202). Features of design to facilitate rust-proofing of engineering structures and machinery are enumerated. Practical hints are given.

Automatic Spray Finishing Unit Increases Efficiency of American Steel Company. (*Ind. Fin.*, 1958, **10**, Apr., 38–39). Drum-type containers are coated and stoved.

Influence of pH of Metallic Surfaces on the Adhesion of Paints. C. Hess. (*Pein. Pig. Ver.*, 1957, **33**, Sept., 798–800). The influence of the pH of the final rinsing solution, following treatment with phosphoric or chromic acid, on the adhesion of paint film is discussed. The pH of the final solution should be 3–5.

POWDER METALLURGY

Powder Metallurgy. N. Corsini. (*Riv. Mecc.*, 1957, **8**, Oct., 12, 7–56). [In Italian]. This paper gives a detailed review of present day developments in powder metallurgy. The fundamentals of the process are described and the mechanical and physical properties of sintered metals are analysed. Certain special characteristics of sintered powders are examined such as their ability to be combined with non-metals. A review of modern applications is given as well as a glossary of technical terms.—M. D. J. B.

Powder Metallurgy. General Development and Future Possibilities in the Fields of Refractory Machine Parts and Cermets. R. Kieffer and R. Meyer. (*Chim. Ind.*, 1958, **79**, Apr., 414–431). A review with 54 refs.

Iron Powder Made by the H-Iron Process. J. F. Kuzmick and K. W. Bruland. (*Met. Prog.*, 1958, **73**, Mar., 92–96). Work of the Alan Wood Steel Co. is described on reduction of high-purity magnetite concentrate with 97% H_2 at 400 p.s.i. and 1000° F. Various grades of powder are produced and their moulding and sintering properties are tabulated and particle shapes illustrated.

Porous Sintered Metals. Their Manufacture and Use. R. Palme. (*Metall*, 1958, **12**, Jan., 28–32). Various methods of making porous compacts of sintered metal powders are briefly described, followed by a discussion of their technological properties with reference to use as reservoirs of other substances, as filters, as throttling elements, for surface absorption, capillary flow, heat transfer by sweat cooling etc., and as high-pressure glands.—J. G. W.

Powder Metallurgy in the U.S.S.R. C. G. Goetzel. (*J. Met.*, 1958, **10**, Mar., 180–181). Non-ferrous powder products and cermets are mentioned.

Synthetic Solids. XIII. The Influence of Surface Layers, Particularly Oxide Layers, on the Sintering of Metals. II. M. Clasing. (*Z. Metallk.*, 1958, **49**, Feb., 69–75). The tensile strength, fracture strain, hardness and density of a sintered specimen, specially of copper, are investigated as a function of preoxidation and grain size of the powder, sintering time and temperature. Effects of sintering *in vacuo* and in hydrogen are discussed.—R. P.

Get Tailor-Made Properties with Sintered Steel. R. Talmage. (*Iron Age*, 1958, **181**, Apr. 3, 104–106). The properties attainable are indicated and various aspects briefly discussed.

Production and Properties of Corrosion-Resistant Sintered Steel. F. Eisenkolb. (**Stahl u. Eisen*, 1958, **78**, Feb. 6, 141–148). The author reviews present production methods for corrosion-resistant sintered steel and discusses methods for the production of powder from austenitic steels. High-chromium steels are difficult to sinter, the sintered parts show high porosity and low strength. The use of liquid-phase sintering by addition of boron and phosphorus overcomes these difficulties. Addition of nickel to steel powder increases the strength and reduces the porosity of sintered parts. Corrosion-resistance is greatly impaired by the porosity of the sintered compacts.—T. G.

Manufacture of Tools from High Speed Steel Turnings. Yu. P. Zimin and K. M. Stroeva. (*Stanki Ins.*, 1958, **29**, (2), 15). Experiments are described in the manufacture of tools by heating and compacting high-speed millings. The results are discussed.

The Effect of Boron on the Formation of Liquid Phases in Sintered Steel, with Particular References to 18–8 Stainless Steel. F. Benesovsky and W. Hotop. (**Stahl u. Eisen*, 1958, **78**, Feb. 6, 149–152). Liquid-phase sintering of steel powder is obtained by addition of a low-melting-point Ni–Cr–B alloy containing Ni 72, Cr 18, B 4·2, Si 3·4, Fe 2·1 and C 0·3%. The resulting sintered steel and iron parts show high density, ultimate tensile strength, hardness and toughness. The sintered parts of 18–8 stainless steel are highly corrosion- and scale-resistant and show also a high wear-resistance.—T. G.

Use of Mill Scale for the Fabrication of Machine Parts by the Methods of Powder Metallurgy. A. Domsa and G. Müller. (*Acad. Romine Met.*, 1957, **2**, (1–2), 79–85). Iron powder production is described and its compaction in methane. **The Use of Lubricants in the Pressing of Metal Powders.** A. Domsa, V. Moldovan and V. Nicolae. (87–98). **Some Problems of the Metallographic Study of Sintered Parts Made from Metal Powders.** A. Domsa and H. Colan. (99–111). Iron powder parts are mainly examined.

On the Use of High-Frequency Heating for the Sintering of Metal Powders, Especially Refractory Powders. A. Domsa, G. Müller, T. Bereczki and S. Kovacs. (113–119). W and Fe–W powders were used.

On the Growth of Carbide Particles in the Production of Hard Metal by Powder Metallurgy. (Part I. Dependence of Growth Rate on the Temperature and Sintering Time.) B. Čech. (*Hutn. Listy*, 1958, **13**, (2), 113–118). [In Czech]. In the course of experiments on the growth of the larger carbide grains during sintering of powders of the Cr_3C_2–Ni and WC–Co systems the growth of the particles was found to take place continuously even under isothermal conditions. The rate of growth of Cr_3C in the Cr_3C–Ni system is considerably greater than that of WC in WC–Co at corresponding temperatures in the range 1250–1600° C. In both cases, particle growth is accelerated by additions of binder. The carbide components appears to be transferred to the particles via the liquid phase of the binder. **Part II. Effect of Additions of other Carbides on the Growth Rate.** (118–123). [In Czech]. The effect of additions of WC, TiC, Mo_2C, TaC, NbC or VC respectively, in amounts of 5% by volume on the structural changes occurring during isothermal sintering of Cr_3C_2–Ni at 1320°C was studied. The growth of chromium carbide particles is effectively inhibited by WC additions. The physical basis of the phenomenon is discussed.

Chemical Browning of Porous Steel Parts, Produced by the Sintering Process. P. Csokán. (*Koh. Lapok*, 1957, **12**, July, 317–318). A method is given for chemical browning of sintered porous steel parts. The method consists of oxidizing at 460–480° C for ½–1½ h in steam and it is based on the following chemical reaction: $3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$. The technique of the method is described in detail.

FERRITES, CERMETS AND CARBIDES

Some Magnetic Properties of Mn–Mg–Ferrite with Rectangular Hysteresis Loop. Z. Funatogawa, N. Miyata and H. Sando. (*Sci. Rep. Yokohama Nat. Univ.*, 1957, Sept., 14–20). [In English].

The Oxidation of Solid Solutions of MnO–Fe_2O_3. A. Braginski, K. Fraczek and T. Fraczek. (*Arch. Electrotech.*, 1957, **6**, (4), 597–612). Oxidation of Mn ferrite in air is examined and its effect on magnetic properties.

Investigation of the Magnetization of Ferrites in the Curie-Point Region. K. P. Belov, K. M. Bol'shova and T. A. Elkina. (*Izvest. Akad. Nauk Seriya Fiz.*, 1957, **21**, (8), 1047–1054). The ferrites studied in this work were seven of the Mn–Zn (20–40% MnO) and two of the Co–Zn type with low Curie points. The true magnetization near the Curie point was found to be of the same order of magnitude as for ferromagnetic metals and alloys and could be represented by the same type of thermodynamic equation. The values of the spontaneous magnetization calculated by the thermodynamic coefficient, equal magnetization lines and the magnetization isotherms methods were found to agree well. The magnetic transformation was found to tail off beyond the temperature at which the spontaneous magnetization disappears, and with Mn–Zn ferrites anomalous growth occurred of the coercive force and residual magnetization beyond this temperature.—S. K.

Magneto-Optic Properties of Ferromagnetics in the Infra-Red Region. G. S. Krinchik. (*Izvest. Akad. Nauk Seriya Fiz.*, 1957, **21**, (9), 1293–1296). In the work described the influence of magnetization on the reflection of light from a ferromagnetic was studied over a wide range of wave-lengths, including the infra-red (0·75–9μ). The experimental method is outlined and results are described and discussed.—S. K.

Magnetic Viscosity of Ni–Zn Ferrites during Free Change of Magnetization. I. A. Lednov and R. V. Telesnin. (*Izvest. Akad. Nauk Seriya Fiz.*, 1957, **21**, (9), 1280). This is a brief account of a report on a new method of measuring magnetic viscosity and results obtained by its use. The full report is in *Radiotekhnika i Elektronika*, 1956, **1**, 1186.

Some Magneto-Optic Effects with Micro-Waves. N. N. Neprimerov. (*Izvest. Akad. Nauk Seriya Fiz*, 1957, **21**, (9), 1288–1292). The author describes his methods and the results obtained when studying the Kerr effect with microwaves ($V = 9375$ MHz). The materials used included magnetite and nickel–zinc ferrite. Curves showing the dependence of the polarization plane rotation on the field for Ge are given.—S. K.

Radio-Frequency Magnetic Spectra of Mixed Ferrites. L. A. Fomenko. (*Izvest. Akad. Nauk Seriya Fiz.*, 1957, **21**, (9), 1310–1317). In this work new experimental data are presented on the investigation of the radio-frequency magnetic spectra of mixed ferrites, measured in very weak fields in the frequency range 0·2–60 MHz. The results obtained are discussed and methods of describing the spectra are proposed. Over 100 toroidal specimens of Ni–Zn–, Ni–Zn–Cu–, Ni–Zn–Be–, Ni–Zn–Mg–, Li–Zn– and Mn–Zn ferrites with initial permeabilities from several tens to 2000 Gs. Oe^{-1} were used. The influence on the nature of the spectra of various factors was studied, including technological variations associated with large-scale core manufacture.

What's Happening to Cermets? J. W. Graham and W. F. Zimmerman. (*Met. Prog.*, 1958, **73**, Mar., 89–91). Resistance to corrosion and impact strength are considered. Various uses are mentioned.

Cermets of Aluminium Oxide and Iron or Iron Alloys. W. Jellinghaus and T. Shuin. (*Stahl u. Eisen*, 1958, **78**, Apr. 3, 419–429). Production and properties of these cermets are described. Cermets up to 13 wt.-% (22 vol.-%) Al_2O_3 can be rolled.—T. G.

New Alumina-Type Cermets. T. F. Frangos. (*Mat. Design Eng.*, 1958, **47**, Feb., 112–115). Properties and uses are discussed and typical shapes shown.

Alumina Base Cermets. Adherence between Alumina and Chrome. H. Matsumoto, S. Yamaguchi and G. Nishiyama. (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1957, **6**, Feb., 110–114).

Experimental Researches on the Specific Properties of Hard Cermet Materials of Roumanian Manufacture for Metal Working. E. Lăbuscă and N. Lăbuscă. (*Acad. Roumine Met.*, 1957, **2**, (1–2), 121–136).

PROPERTIES AND TESTS

Steel Specifications. H. H. Jackson. (*Bull. Inst. Met.*, 1958, **6**, Apr., 21–25). A lecture from the consumer's standpoint.

German Steel Specifications. J. Götzlinger. (*Tek. Tidsk.*, 1958, **88**, Mar. 11, 209–210). A description of the German DIN 17, 100 and the recent German publication dealing with the preliminary selection of steel qualities for welded steel structures.—L. D. H.

Evolution of Steel Industry Product Standards. J. W. W. Sullivan. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 637–650). A general discussion with 26 references.

Some Problems of the Theory of Metal Structures and Their Mechanical Properties.

T. D. Dulămită. (*Acad. Romine Met.*, 1957, **2**, (3), 375–382). The assumptions concerning the relationship of electrical and mechanical properties, conditions of plastic deformation and heat treatments are discussed.

Assessment of Surface Finish: A New Interference Microscope. (*Iron Steel*, 1958, **31**, Feb., 63–64). A new instrument has been introduced by C. Baker of Holborn Ltd. for the assessment and control of surface finishes, using interference microscopy. It is simple in construction and operation, depending on the provision of a visual assessment of an area, and the optical system uses only one objective. Details are given of the construction, the optical system, and the method of operation.

The Ductility of Vacuum-Cast Steels. V. Hašek. (*Hutn. Listy*, 1958, **13**, (3), 221–225). [In Czech]. Torsion tests in the range 1000–1380° C were carried out on specimens made from several low-alloy Cr–Ni steels which had either been vacuum cast or cast by conventional methods. The tests showed that due to a finer structure and absence of dendrite formation the vacuum cast steels had a significantly higher ductility in the transverse and longitudinal directions of the rod-shaped specimens; the relative superiority over the conventionally cast steels was maintained even after forging.—P. F.

Deoxidation and Hot-Ductility of Type 310 Stainless Steel. R. A. Perkins and W. O. Binder. (*A.I.M.M.E. Elec. Furn. Steel Conf. Proc.*, 1956, **14**, 123–141). Hot-shortness is considered and, in the experiments, melting and pouring practices, composition, hot-working and testing were kept constant so that deoxidants were the only variable. Mn, V, Si, Al, Ce, Ti, Zr and alloys, and Ca were used, either by surface addition or submerged. Hot tensile values, inclusions and microstructures were examined for all additives and related to ductility. High level ductility at 2400° F and a fully austenitic structure with a favourable type of inclusion distribution was best secured with 0·1–0·2% Ca as Ca–Si.

Orientation and Anisotrophy in Low-Carbon Steel Sheets. R. S. Burns and R. H. Heyer. (*Sheet. Met. Ind.*, 1958, **35**, Apr., 261–275). Sheets from the top and middle of ingots from 7 heats of rimmed steel and the same from Al-killed low-C steel were used. Compositions and tensile values are given. Plastic anisotrophy was investigated, a tear-length test was performed, preferred orientation was identified and torque magnetometer test were made. The results are discussed and the principal cause was shown to be mechanical fibre due to inclusions and iron carbide stringers. X-Ray pole figures gave crystallographic textures correlating with plastic anisotropy but not closely to magnetometer curves.

Mechanical Properties of Steel with Austenite–Martensite Structure. A. L. Nemchinskii, N. M. Fokina and I. L. Shimelevich. (*Metall. Obra. Met.*, 1956, (1), 30–35). The limit of plasticity and strength of steel with austenitic–martensitic structure with quantitative increase in martensite, grow rapidly at first and then gradually slow down. The theory of Scott, regarding a sharp intermittent increase in these limits during the arrangement of the martensite network is not confirmed. In steels with increased carbon content plasticity ceases after a relatively small increase in the martensite transformation (10–20%).—L. H.

Change in Relaxation Characteristics of Some Steels During Prolonged Tests (10,000 hours). T. I. Volkova. (*Metall. Obra. Met.*, 1956, (1), 18–25). The experiments on relaxation here described based on 10,000 h duration have given some quantitative characteristics for relaxation for 4 types of steel at 410° and 470° C. At the lower temperature, in tests lasting 2000–2500 hours sufficiently reliable data were obtained to allow for their extrapolation to 10,000 hours. At 470° the duration of investigations has to be extended to about 5000 h to obtain reliable data. The findings for each type of steel investigated are set out in detail.—L. H.

Internal Friction. P. M. Robinson and R. Rawlings. (*Iron Steel*, 1958, **31**, Jan., 3–7; Feb., 65–68; Mar., 97–100). The authors define internal friction, classifying its various types, and outline direct and indirect methods of measuring it. The effects of interstitial and substitutional elements are discussed, and the application of internal friction measurements to the study of diffusion and precipitation is described, with particular reference to carbon and nitrogen in steels. Stress relaxation across grain boundaries and phase interfaces, an important source of internal friction, is considered, and finally the effects of dislocations and vacancies in metals are described.—G. F.

Internal Friction, A Useful Physical Magnitude in Metallurgy. (I). B. Rothenstein and J. Hrianca. (*Mei. Constr. Masini*, 1957, (11) 8–12). [In Rumanian]. Internal friction is very sensitive to a great many factors both internal and external and finds many applications in the physics of metals and polymers. After defining some necessary values used in its determination: angle of loss i.e. the difference between the maximum periodical stresses and maximum periodical deformations and the logarithmic decrement i.e. the natural logarithm of the ratio between two successive amplitudes in oscillations in the same sense, the methods of measuring internal friction are given: the torsion pendulum, the electrostatic, the piezoelectric, the Foucault currents and the electromagnetic methods, followed by a theoretical explanation of the internal friction.—L. H.

Influence of Microstructure on the Carbon Damping Peak in Iron–Carbon Alloys. P. Stark, B. L. Averbach and M. Cohen. (*Acta Met.*, 1958, **6**, March, 149–155). The height of the internal-friction peak associated with the stress-induced migration of carbon in ferrite was found not to correspond with the true solubility at the temperature of carbide solution when the grain size or intercarbide distance is small. It is suggested that part of the carbon is not retained in solution despite rapid quenching. The effect is independent of total carbon content for a given grain size and inter-carbide distance. The same effect is observed for tempered martensite structures.

The Effects of Grain Size and Texture on the Internal Friction in α-Iron Due to Interstitial Solutes. G. Lagenberg and E. G. Wolff. (*Acta Met.*, 1958, **6**, Feb., 136–137). A redetermination shows that texture lowers internal friction and that grain size has a similar but lesser effect, and the conclusions of an earlier investigation (*ibid.* 1955, **3**, 236), are modified.—A. D. H.

Ductility in High-temperature Rupture Test. J. Glen. (*J.I.S.I.*, 1958, **190**, Sept., 30–39). [This issue].

The Effect of Quench Aging on the Notch Sensitivity of Steel. J. R. Low, jun. (*Welding J.*, 1957, **36**, Oct., 464s). With reference to keyhole Charpy tests carried out in 1952 and reported in *Welding J.*, 1952, **31**, May, 253s–256s, a further series of tests have been carried out and results obtained showed that there was no change in the Charpy curve as a result of six years of additional aging.—U. E.

Statistical Evaluation of Toughness Test Results for Unnotched Impact Bending Test-Pieces of High-Hardness Steels. K. Bungardt, O. Mülders. and W. Spyra. (*Stahl Eisen*, 1957, **77**, Dec. 26, 1878–1883). Mathematical. 30–40 Tests are required if the relative deviation of the mean value for a statistical probability of 99% is not to exceed 10%.—T.G.

Study of the Deformability of Technical Iron in the As-Cast State. G. N. Mekhed. (*Metallovedenie Obrab. Met.*, 1956, **2**, Aug., 43–47). Rimming or killed irons as cast have low ductility under impact. In static tests it is much higher. Iron killed with Mn, Si or Al has greater ductility than rimmed metal, by 8–10% when rolled in the red-shortness zone at 900–1,000°C. Impact compression tests best disclose embrittlement susceptibility. Increased S and O depress ductility in the range 850°–1,050°C. and indeed the brittleness of technical iron appears to be due to these elements.

Strain Ageing of Mild Steel. Effects of Ferritic Grain Size. A. Nakanishi. (*Tetsu to Hagane*, 1955, **41**, Sept., 967–969). [In Japanese.] The specimens are classified by grain size, and the changes of tensile strength and ageing index during the course of ageing are followed for the different groups. The results are explained in terms of dislocation theory.—K. E. J.

On the Effect of Working Velocity on the Stored Energy of Cold-Worked Armco Iron. T. Yamane. (*Tetsu to Hagane*, 1955, **41**, Sept., 1058–1059). [In Japanese.] Data are given for the stored energy and energy of working produced by compression in a press and by a drop-hammer for different values of the strain.—K. E. J.

Application of Strain Hardening Curves. (*Mech. World*, 1957, **137**, Oct., 464–465). The use of these curves to analyse the possibilities of reductions in forming and the need for intermediate annealing for drawing and pressing operations is explained. Graphical methods are used.

On Rigid Workhardening Solids with Singular Yield Conditions. W. E. Boyce and W. Prager. (*J. Mech. Phys. Solids*, 1957, **6**, (1), 9–12). Mathematical.

Equipment for Relaxation Testing. R. Pech, P. Jehlička, J. Šorm and J. Vlíc. (*Hutn. Listy*, 1957, **12**, (12), 1103–1106). [In Czech.] The design and performance of two types of relaxation testing machines of Czechoslovak manufacture are described. One is spring-loaded, the other one utilizes a variable load. Tests of 1,000 h duration carried out at 500°C on a Cr-V-W steel showed virtually identical relaxation curves on the two machines.—P. F.

Tests with Relaxation Frames. R. Pech. (*Hutn. Listy*, 1957, **12**, (12), 1106–1108). [In Czech]. Improvements in the use of relaxation blocks (frames) are described. In these tests the specimen, provided with threaded ends, is fixed in the extended position into a rigid block (frame). Its gradual elastic deformation is used to obtain its relaxation curve.—P. F.

Tests with Relaxation Rings. J. Kermes. (*Hutn. Listy*, 1957, **12**, (12), 1108–1111). [In Czech]. The use of sickle-shaped rings, wedged open at the sharp points, for studying relaxation and creep of alloy steels is described. The theoretical processing of the results, as well as technological equipment for relaxation testing of many samples are described.—P. F.

The Significance of Relaxation Studies at High Temperatures in Components of Complex Shape. J. Němec. (*Hutn. Listy*, 1957, **12**, (12), 1111–1115). [In Czech]. The utility and theoretical aspects of high-temperature stress-relaxation studies in structures and components of complex shapes are considered.

Fatigue Life as a Function of Surface Conditions. D. E. Swets and R. C. Frank. (*Metallurgia*, 1957, **56**, Nov., 230). Fatigue tests on SAE 52100 steel specimens show that clean oil-free specimens have a distinctly shorter fatigue life than specimens coated with lubricating oil. The effect is felt to be due solely to surface condition and is rapid, as oil-free specimens broke within 10–15 min.—G. F.

On the Fatigue Test of Hollow Drill Steels by an Electromagnetic Resonance Type Fatigue-testing Machine. M. Uchiyama. (*Tetsu to Hagane*, 1955, **41**, Sept., 923–926). [In Japanese]. Results are given for a large number of imported plain-carbon, C-V, high C-Cr-Mo, high-C-Cr, C-Ni-Cr, high Ni-Cr-Mo, and low Ni-Cr-Mo steels.—K. E. J.

Creep Stability of Columns and Plates. G. N. Rabotnov and S. A. Shesterikov. (*J. Mech. Phys. Solids*, 1957, **6**, (1), 27–34). Two forms of theory based on strain hardening are used. The flow theory and strain theory are compared for the case of a compressed plate.

Relation Between Creep Strength, Hardness and Microstructure of 12% Chromium Heat-resisting Steels. T. Fujita. (*Tetsu to Hagane*, 1955, **41**, Sept., 988–990). [In Japanese].

Effect of Alloying Elements and Heat Treatments on Creep Properties of 12% Chromium Steels. T. Akutagawa. (*Tetsu to*

Hagane, 1955, **41**, Sept., 986–988). [In Japanese]. Creep properties are given for 12% Cr steels alloyed with Mo, Nb, W, V or Ti for two types of heat-treatment, viz., solution-treatment at 1150° or 1000° C for 30 min and oil cooling, followed by ageing at 680° C for one hour and air cooling.—K. E. J.

Industrial Failure of Engineering Metals and Alloys. B. R. Nijhawan (editor). (*Symposium Organised by the National Metallurgical Laboratory, Jamshedpur, Feb.*, 1953. *Publication of the Council of Sci. and Ind. Res., India*, 1957, pp. 347). **Service Failures of Engineering Metal Components.** B. R. Nijhawan. (1–16). Failures of machine parts due to unsuitable materials, faulty melting amd processing, faulty heat treatment, poor machining and surface finish, careless handling, and the effects of stress raisers in fatigue are described. **A Contribution to the Service Failure of Large Chilled Iron Rolls Due to Fatigue.** H. Shimoda and S. Onodera. (17–30). The rupture in service of a chilled iron roll due to fatigue is described and redesign to remedy the defect is explained. **Failures of Steel Parts in Service.** R. A. MacGregor (31–35). Early cases of fatigue failure are briefly outlined. **A Summary of Some Typical Steel Failures in Machine Parts and Structural Sections.** E. W. Pierce (36–51). Examples of failure by fatigue, crack propagation and corrosion are given and illustrated. **Some Observations on Failures in Aircraft Engines and Fuselage Parts.** S. C. De and G. P. Contractor. (52–60). Fatigue failure in steel engine parts are noted. **Contribution to the Knowledge of Procedures Going on during Cyclic Stressing of Materials.** M. Hempel and E. Houdremont. (61–81). Changes in microstructure and crystal structure of mild steel after cold straining and cyclic stressing are discussed. Heat developed is evaluated as a cause of crack initiation, and propagation is considered. **Some Characteristic Service Failures of Rails.** S. C. De and T. V. N. Kidao. (82–94). Types of failures are discussed and illustrated. **The Overheating and Burning of Steel.** K. Tsun. (95–104). A summary of the phenomena in the overheating of steel for forging with microstructures. **Cracking of Bucket Lugs in Pelton Turbines, a Corrosion Fatigue Phenomenon.** A. B. Winterbottom. (105–110). Typical failures are shown and remedies suggested. **Service Failures of Railway Materials.** R. G. Bhatwadekar and S. Ramanujam. (111–116). Fatigue failures of tyres, coupling rods, axles and other parts, rails and fish plates are briefly described.

Ultrasonic Flaw Detection for Cast Iron. N. B. Khimchenko. (*Lit. Proizv.*, 1957, (8), 15–18). [In Russian]. A method is described for ultrasonic defectoscopy with the use of the instruments U3D7 and 86 IM. The influence of the form and parameters of the free graphite particles on the dispersion of ultrasonic waves can be utilized for the determination of the size of the graphitic inclusions in cast iron specimens.—L. H.

The Ultrasonic Radiation Field and its Importance in the Testing of Materials by the Dip Technique. J. Krautkrämer. (*Z. Metallk.*, 1957, **48**, Nov., 606–609). The influence of the size of a defect, its location in relation to the axis of the ultrasonic beam and the frequency are deduced. It follows, for a given quality of transducer, that the maximum rate of testing is a function only of the size of the defect, and that the testing speed can be increased by improving the quality of the transducer.—L. D. H.

Surface Examination by Radiation. A. E. Williams. (*Ind. Fin.*, 1957, **9**, July, 685–686, 688–690). A review of X-ray and isotope methods.

Inspection of Workpieces by Means of an Intensified X-Ray Image. G. Lang. (*V.D.I.Z.*, 1957, **99**, Sept. 1, 1227–1231). X-Ray radiographic equipment coupled to a cathode-ray tube is described and its application to radiography of metal parts is discussed.—J. G. W.

The Versatility of Radiation Applications Involving Penetration or Reflection. C. E. Crompton. (*International Conference on the Peaceful Uses of Atomic Energy*, June, 1955, A/Conf. 8/P/164, pp. 20). A review of sources and applications of β and γ rays and neutrons is given, not all metallurgical; including thickness and similar gauging processes.

Material Testing by γ-Rays. II. Experimental Model of an Automatic Recording Scintillation Gamma Spectrometer. T. Watanabe. (*Rep. Gov. Ind. Res. Inst.*, 1957, **6**, Mar., 153–162). A NaI crystal activated with Tl was used, an EMI 6262 photomultiplier tube, a linear amplifier, and other components. The resolution is 12·4% at the photo-peak of the γ-ray of ^{137}Cs and the relation of energy to pulse height is accurately linear.

Nucleonic Thickness Gauges in Steam Engineering. J. F. Cameron. (*Steam Eng.*, 1957, **27**, Nov., 53–55, 69). A review of the artificial radioactive isotopes and gauges employing them and examples of their use is given.

The Irradiation Strength of Radioactive Isotopes. H. Möller and H. Weeber. (*Arch. Eisenhütten.*, 1957, **28**, Sept., 543–546). Irradiation tests were carried out with ^{192}Ir, ^{137}Cs, and ^{60}Co. For steel thicknesses ranging from 15 to 60 mm Ir was found to be indispensable, yielding images of high quality. There was little difference in the quality of the images obtained with Cs and Co radiations.

The Effects of Irradiation on Structural Materials. F. E. Faris. (*International Conference on the Peaceful Uses of Atomic Energy*, June, 1955, A/Conf. 8/P/747, pp. 19). A compilation of U.S. investigations, mainly non-ferrous.

Electron Diffraction from Crystals Containing Stacking Faults: II. M. J. Whelan and P. B. Hirsch. (*Phil. Mag.*, 1957, **2**, (8th Ser.), 1303–1324). The theory previously advanced is applied to stainless steel and the observations are in agreement and suggest stacking faults on (111) planes.

Thermal Conductivity and Temperature Diffusivity in Cast Irons. B. B. Kuprovskii and P. V. Gel'd. (*Lit. Proizv.*, 1956, (9), 16–18). [In Russian]. With increasing carbon content, temperature diffusivity of cast irons with lamellar graphite increases. In cast irons with nodular graphite such a relation cannot be observed. At low temperatures (100–200°) the temperature diffusivity of cast iron with lamellar graphite (containing 4·12% C) is twice as much as for a cast iron with nodular graphite, but at 900° they do not differ in diffusivity.—L. H.

Simplification of the Determination of Thermal Conductivity in Steels. L. A. Brovkin. (*Zavod. Lab.*, 1957, **23**, (8), 929–931). [In Russian]. A new method is proposed for the simplification of the determination of the coefficient of thermal conductivity of solids. It is relatively simple both as regards the setting up of the experiments and as regards the interpretation of the data obtained. The results satisfy technological requirements.

Improvement in the Method of Determining Simultaneously the Heat and Electrical Conductivity of Steels. R. E. Krzhizhanovskii. (*Zavod. Lab.*, 1957, **23**, (8), 925–927). [In Russian]. A modification to an existing apparatus allows of a six-fold speeding up of the production of vacuum, and by a series of other measures it was found possible to determine the thermal and electrical conductivities at a given temperature within 1·5–2 h.—L. H.

On Thermodynamics in Metallurgy. A. Podgornik. (*Rudarsko-Metalurški Zbornik*, 1957, (2), 95–108). [In Serbo-Croat]. The present state of thermodynamics in metallurgy is reviewed. It is shown that by means of Oelsen's thermodynamic methods, involving only calorimetry and thermometry, it is possible to obtain thermodynamic potentials and activities without needing to introduce extraneous assumptions. The method facilitates the rapid development of equilibrium diagrams and the checking of the accuracy of those already existing.—P. F.

A New Automatic Instrument for Differential Thermal Analysis. Z. Pospíšil and M. Beránek. (*Silikáty*, 1957, **1**, (2), 116–124). [In Czech]. A new analyser is described, in which pressed cup-shaped samples are used. Temperature is checked by means of an automatic step compensator operating on a null method. The thermocouple is not in direct contact with the material studied, but projects inside the hollow of the inverted sample.—P. F.

Vapour Pressures of Liquid Iron and Liquid Nickel. J. P. Morris, G. R. Zellars, S. L. Payne, and R. L. Kipp. (*U.S. Bur. Mines Rep. Invest.*, 1957, No. 5364, Sept., pp. 10). Gas transport measurements at 1540 and 1620° C gave a value for iron of log Pmm = — 19460/T + 9·147.

Thermal Expansion Coefficients for 51 Metals. W. A. Tucker. (*Prod. Eng.*, 1957, **28**, Mid-Oct., B12–B13). Mostly non-ferrous.

Contribution to the Calculation of the Viscosity of Molten Metals. A. Hrbek. (*Z. Metallk.*, 1957, **48**, Nov., 603–605). A relationship is developed which makes possible the determination of viscosity and self-diffusion in molten metals over a wide range of temperatures, a linear relationship was established between the reduced activation energy and the superheating of the melt above its melting point.—L. D. H.

Influence of Temperature and Shape on the Characteristic Viscosity of Steels. T. A. Vladimirskii. (*Zavodskaya Laboratoriya*, 1957, **23**, (7), 830–837). [In Russian]. An essential feature of the investigation was the construction of viscosity temperature graphs during variation in shape. It was further necessary to work out a technique for making small incisions of the order of 0·01 mm. For the critical temperature of brittleness, the upper level of brittleness was taken corresponding to an impact viscosity of 2 Kg/cm². The tabulated results justify the conjecture that the reciprocal influences of the various factors during these stress experiments are very complex, so that this excludes the acceptance of the simple principle of additive effects.

Organisation of Research on the Long-Term Heat-Resistance of Steel. S. Arwidson. (*Arch. Eisenhütt.*, 1957, **28**, Nov., 673–674). A description is given of the work and organization of the Swedish Heat Resistance Commission which was appointed in 1946. Its 4 sub-committees deal respectively with test apparatus and methods; embrittlement; the effects on long-term strength of structure, grain size, and casting structure; and the effects of fluctuating loads and temperatures.—L. J. L.

Measurement of Autodiffusion Constants in α-Iron Using Radioactive Tracers. C. Leymonie, P. Lacombe, and C. Libanati. (*Compt. Rend.*, 1957, **245**, Nov. 25, 1922–1925). The energy of activation was found to be 64 Kcal/g atom and the frequency factor 18 cm²/sec.

The Effect of Annealing at 1200° C on the Energy of Activation for Diffusion of Chromium in Iron–Chromium Alloys. A. G. Lesnik. (*Problems of Metal Physics and Metallography, Ukranian Acad. Sci. Met. Phys. Lab.*, 1954, (5), 118–122). Six alloys were studied and the ordering process in austenitic, ferritic, and mixed alloys is discussed.

Electrolytic Transfer of Carbon in Liquid Iron–Carbon Alloys. M. A. Rabkin. (*Zhur. Prikl. Khim.*, 1957, **30**, (5), 791–794). [In Russian]. The movement of carbon under the action of an applied electric potential was studied in an alloy of the following composition: 3·65% C, 0·72% Mn, 1·88% Si, 0·05% S, and 0·074% P. The results showed the carbon to exist in the form of positively charged ions. The difference in carbon concentration at the electrodes increases with duration of the application of the electric field. The sulphur appears from preliminary experiments also to exist in the form of positive ions. Details of apparatus and experimental conditions are given.—S. E.

Unsteady-State Method of Measuring Thermal Diffusivity and Biot's Modulus for Alumina Between 1500° and 1800° C. A. E. Paladino, E. L. Swarts, and W. B. Crandall. (*J. Am. Ceram. Soc.*, 1957, **40**, Oct., 340–345).

On the Cathodic Hydrogen Evolution Process. W. Palczewska and M. Smialowski. (*Proc. Electrochemical Conference 1955, Warsaw*, 1957, 219–270). **Deformation of Iron Wire by Penetration of Cathodic Hydrogen into the Surface Layer.** A. Krupkowski and M. Smialowski. (271–299). (Abstract below). **The Influence**

of the State of Polarization on the Brittleness of Iron and Nickel Due to the Penetration of Hydrogen. M. Smialowski and Z. Szklarska-Smialowska. (301–318). Test-pieces and conditions as in the previous paper were used. **The Susceptibility of Steels to the Action of Cathodic Hydrogen in Relation to their Chemical Compositions.** J. Foryst and M. Smialowski. (319–326). Measurements are made on Armco iron and an expression advanced for hydrogen-brittleness. **The Influence of Cathodic Hydrogen on the Magnetic Properties of Mild Steel.** L. Kozlowski. (327–351). Coils of iron wire were studied in arsenical H_2SO_4. (Discussion, 352–362). **The Effect of Polar Organic Compounds on the Catalytic Poisoning of Hydrogen Overvoltage on Iron and Nickel Cathodes.** W. Palczewska. (363–384). **The Time-Dependence of the Potential of Polarized Iron and Nickel Cathodes.** Z. Syklarska-Smialowska. (385–401). (Summary and Discussion, 459–481).

The Effects of Chemical Composition and Structure on the Behaviour of Hydrogen in Iron and Steel. F. Erdmann-Jesnitzer and P. Dammköhler. (*Neue Hütte*, 1957, **2**, Oct., 637–645). Experiments are reported on butt-welded samples of killed and unkilled carbon steels with a maximum of 0·3% by weight of carbon. There was no indication that the strength of unkilled steel is inferior to that of killed steel. Butt welds of thin sheet inhibited welding cracks mainly in the unkilled steel which are attributed to the effect of H_2 and the inhibiting effect of Si on the migration of H_2 into the base material.—L. J. L.

Hydrogen and Eddy Current Losses in Iron of Various Silicon Contents. F. Erdmann-Jesnitzer, and K. Schreck. (*Neue Hütte*, 1957, **2**, Oct., 626–636). The magnetic behaviour of ferromagnetic substances, the effect of the Si content on the magnetic properties, the influence of impurities such as C, Al, Mo, Mn, and Cr, H_2 permeability and absorption and Si content are discussed. Magnetic measurements and results are reported and evaluated.

The Behaviour of Hydrogen in Iron. M. Smialowski. (*Neue Hütte*, 1957, **2**, Oct., 621–626). The dilation effects caused by the diffusion of H_2 into iron are discussed; the diffusion coefficient of H_2 in iron at room temperature and the probable effect of the "bubble layer" on the observed values of this coefficient are examined; and the form in which H_2 occurs in the iron lattice is described.

The Effects of Chemical Composition and Structure on the Characteristics of Hydrogen in Iron and Steel. W. Wichmann. (*Neue Hütte*, 1957, **2**, 618–620). The influence of Si, C, and cementite, and of the structure on the behaviour of H_2 in unalloyed steels; the effect of Si and of temperature on H_2 migration in steel; elastic deformation and H_2 diffusion in soft iron; and plastic deformation and H_2 behaviour in the formation of flaws in unalloyed steel are discussed.—L. J. L.

Hydrogen in Steel, With Particular Reference to Flakes and Fractures Occurring in Steels at High Temperatures. V. Koševlev. (*Neue Hütte*, 1957, **2**, Oct., 601–604). Examples and illustrations are presented to elucidate the connection between (1) H_2 pressure in the steel and (2) internal stresses as a function of the temperature at which the transition from the γ to the α phase occurs.—L. J. L.

Deformation of Iron Wire Under the Influence of the Penetration of Hydrogen into the Surface Layers. A. Krupkowski and M. Smialowski. (*Arch. Hutn.*, 1956, **1**, (2), 101–118). Armco iron wire was measured during cathodic polarization in dilute sulphuric acid in presence of As_2O_3 at 8° C. Elongation was measured and pressure of H_2 calculated in blisters formed mainly in the middle layer. The pressure appears to be $\sim 10^8$–10^9 atmos.

Solubility and Activity of Oxygen in Liquid Iron, Nickel, Cobalt and Their Alloys. V. V. Averin, A. Yu. Polyakov, and A. M. Samarin. (*Izvest. Akad. Nauk, Otdel. Tekn. Nauk*, 1957, (8), 120–122). [In Russian]. It has been found that in liquid iron–cobalt and iron–nickel alloys the saturation concentrations of oxygen have a minimum at high nickel and cobalt contents. This minimum does not occur with nickel and cobalt alloys. Changes in the oxygen concentration in Fe–Ni and Fe–Co alloys do not show a minimum at gas-phase partial pressures of oxygen below values corresponding to the saturated solutions. To obtain saturation concentrations of oxygen in high nickel or cobalt alloys, values of oxygen potential in the gas phase many times in excess of the corresponding value for iron are required.—S. K.

The Influence of Nitrogen on the Mechanical Properties of Sulphur Cast Iron. B. V. Bauman. (*Lit. Proizv.*, 1957, (8), 24–26). [In Russian]. A detailed gas analysis has shown that the cooler the metal the more powerful the oxidation. The treatment with nitrogen lowers slightly the oxygen content in cast iron, so that atomic nitrogen like hydrogen possess reducing properties. With increase in nitrogen content the isolation of the graphitic enclosures grows.—L. H.

Nitrogen as an Alloying Element in Steels. XVII. The Effect of Nitrogen, Copper and Arsenic on the Decrease of Impact Resistance. Y. Imai and T. Ishizaki. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 194–197). [In Japanese]. Impact resistance is not greatly changed by addition of Cu; it is reduced by adding As, but not so much as with P. Increases of strain-ageing by addition of N_2 are reported for Cu and As-containing steels.

Foreign Elements in Metals and Their Influence on the State of the Surface and Specific Properties. A. Roos. (*Peintures, Pigments, Vernis*, 1957, **33**, Aug., 702–710). Factors influencing the structure of ingots and the surface of the final steel are considered. The properties of steel surfaces in respect of gas adsorption, ionic emission, and oxidation resistance are discussed. An apparatus is described for measuring the speed of anodic oxidation in a liquid electrolyte of metal samples. The results obtained with steel containing variable amounts of Mn between 0·2% and 0·9% are given and discussed.

Examination of Steel St52 with Vanadium or Titanium Addition for Structural Purposes. S. Kronmarck. (*Technik*, 1958, **13**, Jan., 1928). An account is given of the development of a structural steel with a minimum yield point of 28·5 t/in². As the result of experiments, two types of steel for structural plate have reached the production stage, having the compositions 0·16–0·20% C, 0·5–0·7% Si, 1·3–1·5% Mn, 0·15–0·25% V, and 0·16–0·20, 0·61–0·76% Si, 1·19–1·75% Mn, 0·17–0·24% Ti. Work is in progress on their adaptation to structural sections. The paper contains extensive data of the properties of experimental casts after a variety of mechanical and heat treatments.—J. G. W.

Casting Alloy Enters High-Strength Field. E. G. Opsahl and W. H. Sparing. (*Prod. Eng.*, 1958, **29**, Apr. 28, 84–85). Wearpact steel, with B and rare earths, is described and its properties given. Its wear resistance is high and dimensional stability is good. Impact strength is lowered less than usual by low temperatures. Notes on fabrication are given and uses mentioned.

The System of Materials Testing in the Danube Iron and Steel Works in Hungary. R. Forbáth and L. Pöcze. (*Koh. Lapok*, 1957, **12**, Aug.-Sept., 420–423. The central laboratory in the Danube Iron and Steel Works in Hungary contains chemical, mechanical, metallographic physical (X-ray etc.) and also instrument service and checking sections. Besides this there are works laboratories in the blast furnace, ore sintering and O.H. plants and a well equipped large laboratory in the coking plant. The determination of ore humidity is performed by means of infra-red heat lamps. Reference is made to some up-to-date rapid analytical methods, used in the chemical laboratories, e.g. combustion S analysis, volumetric Si analysis, complexometric basicity with this or by conductivity measurement.—F. K.

METALLOGRAPHY

Modern Metallography. H. P. Roth. (*Met. Prog.*, 1958, **73**, Mar., 70–73). A report of a meeting at the 2nd World Metallurgical Congress 1957.

Metallographic Aspects of Low Carbon Steels. L. Habraken and T. Greday. (*Rev. Univ. Min.*, 1957, 9th series, **13**, Nov., 682–692). The first results of a comprehensive study of the structure of low carbon steels after various heat treatments are given and discussed. Beside the existence of pearlitic and martensitic transformations they show the existence of a bainitic transformation and after special thermal treatment a small amount of stabilized austenite. Relationships between the structure observed by the electron microscope and mechanical and physical properties of the steels are described.—B. G. B.

What You Need For a Minimum Metallurgical Laboratory. J. R. Driear. (*Foundry*, 1958, **86**, Mar., 83). A design for a small metallurgical laboratory is presented together with lists of the equipment and basic supplies required.

Microscope Cinematography of Transformation Processes in Metals. F. Gabler and R. Mitsche. (*Metall*, 1958, **12**, March, 362–365). The principles are outlined; the apparatus is described, and examples of applications are given.—L. J. L.

Ore Microscopy Adapted to Ceramics. C. Schouten. (*Chem. Week.*, 1958, **54**, March, 125–132). [In Dutch]. Much useful optical information can be obtained when examining opaque minerals under the ore microscope using vertical illumination and the article briefly describes the procedure to be followed. This optical method is not so well applicable to ceramics because of the translucency of their components but much can be learned concerning their texture, structure, pore shape and distribution, slag occlusions, etc. Numerous etched micrographs appear in the text.

Applications of Electron Microscopy to Metallurgical Research. J. Plateau and R. Tamhankar. (*Mét. Corr. Ind.*, 1957, Oct., 359–381). After a short discussion of the principles involved in electron microscopy the authors discuss the applications of this technique to metallurgical investigations. These include methods of sample preparation, phase changes and precipitation of intercrystalline and intergranular nature, surface phenomena, studies in relation to mechanical properties and the examinations of fumes and dust. (116 references).—R. F.

The Practice of Electron Microscope Investigation of Austenitic Steel EI 257. E. I. Kvashnina and E. A. Bondarenko. (*Metallov. Obra. Met.*, 1955, (1), 34–36). This method renders possible the investigation of the appearance of the carbide phase at a much earlier stage of ageing than is possible by metallographic analysis. The first carbides appear as small chains at the grain boundaries. Carbides of certain types have cross-sections of square, right-angled, parallelogram and triangular forms.—L. K.

The Use of Carbon Shadowing for Investigating the Structure of Metals under the Electron-Microscope. A. V. Smirnova and G. A. Kokorin. (*Zavods. Lab.*, 1957, (12), 1446–1448). [In Russian]. With a special arrangement fully described, test-pieces of various steels were prepared and mounted in the apparatus about 40–50 mm above carbon electrodes through which a powerful current of 60–70 amps was directed. This vapourized the carbon. The electron micrographs, × 18000, are reproduced. This method has given satisfactory results in cases when the usual methods have proved insufficient.—L. H.

Electron-Microscopical Observations of Growth-Defects in Thin Iron Nitride Layers. W. Pitsch. (*Arch. Eisenhüt.*, 1958, **29**, Feb. 125–128). Iron nitride layers were produced by nitriding thin iron foils and studied in the electron microscope. The arrangement of growth defects on various planes is discussed.

Simple Extraction Replicas for the Study of Fine-Particle Phases. J. Ježek. (*Hutn. Listy*, 1958, **13**, (3), 213–220). [In Czech]. It is shown how, by suitable etching methods of metallographic samples, fine precipitates such as carbides may be freed sufficiently from the matrix to be detachable by collodion or formvar films. These are suitable for electron micrography or electron diffraction.—P. F.

Electron Emission Method of Investigating Steels. K. V. Varli, K. A. Michurina and Yu.

A. Shakov. (*Zavods. Lab.*, 1957, (12), 1443–1446). Since sufficient brightness for observing the emission spectrum begins at temperatures above 850°, only the stage of collective crystallization could be directly observed. With pure electrolytic iron the $\alpha \rightleftarrows \gamma$ transformation can also be directly followed. The microstructure of one type of steel at various temperatures is described and illustrated.

Microscope Analysis of Metal Structure. L. Orsini. (*Riv. Mecc.*, 1957, **8**, Sept., 28, 7–10). [In Italian]. The paper describes the chemical preparation of ferrous metal samples prior to study under the microscope. The best modern microscope techniques and associated equipment are also briefly reviewed.

Electrochemical Observations on Metallographic Etching. H.-J. Engell. (*Arch. Eisenhütt.*, 1958, **29**, Jan., 73–76). Etching a metal with an electrolyte solution is an electrochemical process: the determination of current density potential curves for the individual phases, taking the orientation of the crystals into account, provides therefore, a suitable means of assessing the characteristics of new etching agents.—L. J. L.

Reagent for the Electrolytic Etching of Chrome–Nickel Austenitic Alloys. Yu. B. Malevskii. (*Zavods. Lab.*, 1958, **24**, (1), 111–112). The author describes a method of electrolytic etching of austenitic steels of the types 18–8 and 25–20, in which the electrolyte is a 30% aqueous solution of KCl, the current density 0·013–0·020 A/cm² and the duration of etching 20–50 sec. Austenite is dissolved, leaving carbide and sigma phase in relief. Examples of photomicrographs are shown.

Electrolytic Polishing and Electrolytic Etching of Metallographic Sections of Metal–Ceramic Materials with an Iron and Copper Base. O. K. Tedorovich and E. T. Kachkovskaya. (*Zavods. Lab.*, 1958, **24**, (1), 57–60). The electrolytic polishing and etching of cermets with an iron–copper base is described, and illustrated by photomicrographs.—L. D. H.

A Rapid Determination of Non-Metallic Inclusions in Steel by Means of Electrolysis. J. Seki and S. Kitahara. (*J. Sci. Res. Inst.*, 1957, **51**, 215–224). Apparatus using a Pt plate enamelled on one side is used to isolate the inclusions in powdered steel samples. Experiments on carbon and Mn steels are reported. The process takes 3 h.

What Can Be Done to Improve Alloy Phase Nomenclature. A.S.T.M. Subcommittee E4. (*Amer. Soc. Test. Mat., Bulletin*, 1957, Dec., 27–30). A new system of symbols is advanced indicating composition and crystal structure.

Management of a Metallurgical Laboratory. W. W. Edens. (*Trans.A.F.S.*, 1956, **64**, 719—721). A brief review of the sources of samples, equipment, personnel and the keeping of records.

Phase-Contrast Microscopy and Its Applications in Metallography. E. Vyklická. (*Slévárenství*, 1957, **5**, (12), 91–98). [In Czech]. The physical principles of phase-contrast microscopy are explained, and several applications in studies of structures found in carbon and alloy steels are given. The scope of the method, and its usefulness with alloys which are difficult to etch, are discussed.—F. F.

The Constitution of Segregates in Alloys. H. Klemm. (*Metall*, 1957, **11**, Aug., 672–676). The author outlines rules for the symbolic description of segregates in alloys and lists the types of segregates defined for 141 alloys including alloys of iron with Al, As, Be, B, C, P, N, Ta, Ti, Sn, Sb, Cu, Au, Mo, and W.

Progress in the Knowledge of Ferro-Chromium Inclusions. R. Zoja. (*Rev. Mét.*, 1957, **54**, Aug., 617–622). The T.T.T. curves of the decomposition of the internal constituent of typical inclusions in Fe–Cr have been obtained. The results of this work and of other published results enable a much clearer understanding of the nature and properties of these inclusions to be formed.—B. G. B.

Study of Dendritic Segregation of Some Metallic Elements in Iron. C. de Beaulieu and A. Kohn. (*Compt. Rend.*, 1957, **245**, Oct. 7, 1244–1246). Autoradiographic studies show that no segregation occurs in the absence of C. In alloys with ~ 0·4% C, Co hardly segregates at all, Mo very little, Mn, Cu, and W appreciably but less than does As.

Retroactive Segregation of Silicon in Cast Iron. A. A. Zhukov. (*Lit. Proizv.*, 1957, **3**, (11), 21–24). [In Russian]. Present experiments give a very simple explanation for the whitening of iron castings containing sulphur, which is due to segregation of the silicon. Owing to the zonal retroactive segregation of the Si, the last portions of the cast iron to harden are whitened in parts by the Si concentrations which crystallize with the formation of ledeburite particles. This is proved by the fact that these particles are not together but form a kind of very thin spider's web around the periphery of the eutectic austenitic-graphitic particles which solidify first. This can easily be seen from a rough polished surface, as, for example, a brake shoe, the whole central part of which is permeated by bleached regions.—L. H.

An X-Ray Study of Textural Stresses in Two-Phase Alloys. C. J. Newton and H. C. Vacher. (*J. Res. N.B.S.*, 1957, **59**, Oct., 239–243). Stresses due to inhomogeneities are studied in steel and other metals. A 1·05% C steel with 0·74% minor constituents was used and qualitative agreement between X-ray results and theory was obtained.

Fundamentals of Isolating Structural Components in Steels. W. Koch and H. Sundermann. (*Radex Rund.*, (5/6), 1957, Sept., (*Colloquium on Isolation of Structural Components in Metallic Materials*, Mar., 1957), 679–692). [In German]. The authors examine the reasons for variations in pH values near the electrodes during electrolytic isolation from steels in neutral electrolytes. Current density/potential curves in different electrolytes for alloyed and unalloyed steels enable optimum electrochemical conditions for isolation to be predicted. The necessity of maintaining a very narrow range of potential means that the geometry of the electrolysis vessel and the surface of the electrodes must be taken into account. This led to the development of a new electrolysis device. The process causing corrosion during partially passive solution was examined and it was found to be closely connected with changes in potential. A new system of magnetic separation is discussed. **The Structure of Phases Containing Metalloids in Alloys.** H. Nowotny and A. Wittmann. (693–707). An attempt is made to present, as uniformly as possible, the structure of most of the crystalline, intermediate metal/metalloid phases. Structural and chemical conditions important for X-ray identification are discussed. Formulæ for series of mixed crystals and continuous miscibility in certain systems are described. **Occurrence and Separation of Inclusions in Metal Heats.** E. Schwarz-Bergkampf. (708-710). In considering the deoxidation of liquid pig iron, the discrepancy between the chemically determined and the calculated amounts of residual oxygen is discussed. The joint effect of different metals which combine with oxygen is described. **Carbide Examination in Unalloyed Steels. By a New Electrolysis Process.** T. Heczko. (711–724). Carbides can be obtained in relatively large amounts by anodic electrolysis of steel in concentrated iron iodide solution with ice cooling. Some novel processes are discussed for the determination of sulphur and oxygen in electrolytic residues. In low carbon steels, the carbon dissolved in the α-iron was about 0·02%. Up to 0·10% Al in the steel does not affect this figure. There are, however, qualitative differences in steels containing Al and those containing no Al. **A Contribution to the Isolation of Sulphides.** E. Artner. (725–726). Efforts were made to isolate sulphides free from admixtures of carbides and oxides, using flotation methods and density and magnetic separation methods. **Identification of Oxide Inclusions in Killed and Partly Killed Unalloyed and Low Alloy Steels.** E. Piper, H. Hagedorn, H. Kern, and J. Ingeln. (727–737). It is pointed out that an agreement between the values obtained by chemical analysis of the residues and those resulting from the hot extraction process can be expected only in the case of killed or—in a few cases—of partly killed steels. Tests are described to determine in which of the two processes of residues analysis (electrolytic solution or chlorine treatment of the isolates) the losses occur. Detailed instructions are given for five groups of steels for the treatment of isolates after electrolysis of the metallic structural components up to the complete residual analysis of oxide inclusions. **Examination of Metallurgical Processes By Isolation of Residues.** C. A. Müller and E. Plöckinger. (738–753). Slag isolation processes are useful in the examination of deoxidation processes and precipitation conditions of non-metallic inclusions in killed, unalloyed or low alloy steels. The possibility of separating various oxide phases from the liquid steel is considered. The oxygen content of the steel bath prior to deoxidation is only of secondary importance if steel temperature is sufficiently high. For a given composition and steel temperature, chemical composition of the resultant oxide phases has a decisive effect on precipitation conditions relating to the products of deoxidation. **Deoxidation of High Carbon Open Hearth Steels with Ferrosilicon, Aluminium and Calcium Silicide.** E. Plöckinger and A. Randak. (754–767). Reactions during the deoxidation of plain high carbon steels by Si, Al or Ca–Si are examined by isolating the residues of oxide inclusions and by oxygen determinations of furnace, ladle, and ingot samples. Although reaction equilibria of deoxidation with Si and Al or with CaSi occur at approximately the same dissolved oxygen content (0·003% at 1600° C), it is found that deoxidation with CaSi results in twice the amount of inclusions and oxygen after completion of the reactions in the ladle than is the case when Si and Al are used for deoxidation. Heats deoxidized with Si and Al exhibited the same amount of inclusions in the samples from the solidified ingot as in the ladle samples. The heats deoxidized with CaSi, however, had 15 to 20% less inclusions in the ingot than in the ladle samples. The effect of ingot size was not checked. Variations in the amount of inclusions due to preliminary deoxidation and deoxidation by precipitation in the ladle and during pouring are associated with a change in the composition of the inclusions. A comparison of oxide slags in unetched sections showed general conformity between isolated oxides and the slag observed in the polished sections. **Occurrence and Separation of Sulphide Inclusions in Steel and Cast Iron. A Contribution to the Discussion.** E. Plöckinger and A. Randak. (768–770). Apart from the determination of oxides, slag isolation processes enable us to determine the amount of sulphides in steel. If, however, on the basis of sulphide isolation, we try to use equilibrium reactions to judge the state of the liquid steel, certain difficulties arise. A consideration of the FeMnS system shows that, at liquid steel temperature of 1600° C, an FeMnS alloy which contains Mn and S in amounts usually associated with free-cutting steel, is still in the region of complete solubility and this can be proved by undercooling of the reaction of sulphide formation. A test with free-cutting steel is described. **Application of the Chemical Analysis of Residues of Graphitic Fe–C Cast Alloys.** W. D. Gras and W. Wittmoser. (771–775). The authors describe a method of analysing graphitic cast iron which permits quantitative determination of the isolates and separation of the more important constituents of the microstructure after completion of electrolysis. **Exposure and Determination of Oxide Inclusions in High Chromium Steels and Attempts to Isolate Oxides in 18/8 Steels.** E. Piper, H. Hagedorn, H. Kern, and J. Ingeln. (776–783). To obtain uniform solution of the steel, with 13% Cr samples, ascorbic acid was added to the electrolyte and active carbon was added during chlorination. It was essential that the active carbon be free from ash. With 18/8 steel, best results were obtained by pretreating the surface prior to electrolysis in molten stearic acid containing olein. The electrolyte consisted of 20% sodium citrate, 3% sodium chloride, and 1% ascorbic acid. **Isolation Characteristics and Mechanical Properties of Structural Steels.** R. Mitsche and

A. Legat. (784–802). After reviewing the main features of the development of structural steels, the authors discuss the " nuclei " effect and direct determination of the nuclei by topographic electron microscope methods. The link between these methods and the determination of mechanical properties is described. A top-blown killed steel is discussed in relation to various methods of oxidation and deoxidation. **An Examination of the Tempering Process of Low Alloy Tool Steels Containing About 1% Carbon.** H. Krainer, K. Ebner, E. Krainer, and M. Storek. (803–831). After surveying the question of the tempering of tool steels, the tempering behaviour of steels containing 1% C, 1·5% Cr, and 1·45% C, 1·5% Cr and 0·1% V and 1% C, 1% Cr and 1·5% W was investigated. Hardness, variation in length, magnetic properties and carbide isolation were studied and the structure was examined both by X-ray and electron microscope methods. **Non-Metallic Inclusions in Free-Cutting Rimming Steel.** H. Hoff, G. von der Dunk, and H. Lessing. (832–839). The characteristics of slag globules found in normal shaped ingots and in bottle-shaped ingots are compared. The suitability of three methods of determining inclusions is discussed. The methods are the Kuschmann-Dunk washing process, the Klinger and Koch process and oxygen determination by the vacuum melting process. **A Statistical Examination of the Process for Determining Oxide Inclusions in Steel.** E. Piper and H. Kern. (840–842). Statistical examination shows that th method of oxide residues is a suitable method for killed steels. It permits both type and amount of inclusions to be established. With unkilled steels, oxygen losses occur during chlorination and also probably during electrolysis, and must not be related only to losses of oxide inclusions. There appears to be a connection between Mn content of unkilled samples and the magnitude of the difference in the method of oxide residues and the hot extraction process. **A Contribution to the Topological Exposure and Identification of Structural Components in Metallic and Refractory Materials.** F. Grasenick. (843–856). A discussion of the isolation of structural components is given whilst preserving their original positions. The use of stereo-photographs to show spatial position to a depth of more than 50 microns is illustrated.—R. S.

The Effect of Low Carbon Contents on the Recrystallization of Iron. F. Haessner and P. Schwaab. (*Arch. Eisenhütten.*, 1957, **28**, Sept., 583–590). Primary crystallization, and grain growth in the α-region of cold-rolled pure iron sheet have been studied, the decrease in thickness, annealing temperature, and duration of annealing being varied. Two pure irons, having 0·006% C and 0·0015% C respectively, were studied to determine the effect of low carbon content, a third material, with 0·003% C and other impurities, being used for comparison. The higher carbon content of the first material led to a reduction of the recrystallization range and recrystallization temperature as compared with the second material.—L. J. L.

Theory and Calculation of the Induction of Elastic Oscillations in Melts. I. I. Teumin. (*Problems of Metallography and Metal Physics, 4th Collection*, Moscow, 1955, 50–69). Effects on crystallization are evaluated, especially in the ultrasonic range under travelling or standing wave conditions. An expression for the power required is obtained and possibilities of practical application are discussed.

On Grain Boundary Displacements During Secondary Recrystallization. M. Žumer and F. Sirca. (*Rudarsko-Metalurški Zbornik*, 1955, (3), 173–179). [In Serbo-Croat]. Recrystallization and grain growth were studied in cold-rolled sheets of silicon iron containing 3·9% Si, 0·06% C, 0·15% Mn, 0·025% S, and 0·018% P. The driving force of grain growth, in the range 950–1070° C studied, is shown to be surface tension, consistent with current views.—P. F.

Hexagonal Steps on the Surface of Fe_2O_4 Solidified from the Melt. N. Miyata and Y. Gondo. (*Science Reports Yokohama National University*, 1956, Section 1, Sept., 27). The phenomenon is illustrated.

Method of Investigating the Tendency of Cast Iron to Growth. N. N. Popova and N. A. Kravchenko. (*Zavodskaya Laboratoriya*, 1957, **23**, (7), 817–818). The growth of cast iron is here defined as its tendency to increase irreversibly its volume on heating at elevated temperatures and especially on repeated heating and chilling. Investigations were made on Mark S Ch 36 cast iron at temperatures between 300 and 350° for 58, 1000, 3000, and 5000 hours, and the linear expansions as well as increases in weight have been tabulated.—L. H.

An Experimental Study of Graphitization of Chill-cast Iron. I. Igarashi and Y. Serita. (*Nippon Kinzoku*, 1954, **18**, Mar., 163–165). [In Japanese]. The graphitization of chill-cast 4·1% C, 0·3% Si irons shows differences between coalesced or eutectic cementite and primary precipitated cementite.—K. E. J.

Investigation on Cast Iron Having Refined Graphite Produced by Melting Cast Iron Covered with Slag Containing TiO_2. VII. Thermodynamic Study on the Ti Contained in S-H Cast Iron. H. Sawamura, T. Mori, and M. Tsuda. (*Tetsu to Hagane*, 1957, **43**, May, 560–564). [In Japanese]. A thermodynamic study was made of the equilibria between Ti and C, and Ti and N in the melt. Formation temperatures of dissolved TiO_2, TiO, and TiS are deduced. 80% of the titanium at 1400–1450° C was in the form of dissolved TiC. (14 references).—K. E. J.

On the Mechanism Underlying the Influence of Surface Oxidation upon the Graphitization of Iron Alloys. K. P. Bunin, G. Z. Koval'chuk, and S. A. Fedorova. (*Doklady A.N.*, 1957, **115**, (2), 281–283). Samples of pearlitic malleable cast iron (C 2·80%, Si 0·91%) were subjected to further graphitization, at 700° C at intervals varying from 1 to 24 h, and the measured amount of cementite gave the measure of half-period of decomposition of the eutectoid cementite. Two sets of samples were studied—those with scale and those free from scale. The graphitizing annealing was carried out on oxidized and in deoxidized lead and in oxidized and deoxidized salt mixtures. The numerical data obtained for half-periods suggest that it is possible to regulate the velocity of diffusion by the variation of external conditions.—S. I. T.

Effect of Silicon on the Graphitization of High-Carbon Steel. S. Koshiba and M. Kikuta. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 70–73). [In Japanese]. The effects of silicon on graphitization were studied by the expansion test, analysis and microscopical examination, and on deoxidation and denitriding by gas analysis. With Si above 0·6%, graphitization is marked, showing two stages during cooling. Graphitization of specimens containing 1·3% Si began from about 600° C in heating. Maximum and minimum degrees of graphitization are related to Si content for annealing at low temperature.

A Contribution to the Study of the Kinetics of White Iron Graphitization. M. Ferry. (*Rev. Mét.*, 1957, **54**, Aug., 586–596). Using a dilatometric method and carrying out the tests in an A atmosphere the kinetics of graphitization at constant temperature of six industrial grades of white iron have been studied. A formula has been derived which relates the percentage of transformation with the time and is claimed to be more accurate for non-hardened industrial iron than that derived by Burke and Owen from a study of the Fe–C–Si system. The effect of annealing temperature and duration of treatment on the number of nodules finally present in iron was also studied.

Influence of Oxidation on the Graphitization of Cast Iron. K. P. Bunin, G. Z. Koval'chuk, and S. A. Fedorova. (*Lit. Proizv.*, 1957, **3**, (7), 15–16). [In Russian]. Experiments are described with two series of specimens, one cleaned of surface scale and the other not. After annealing, the surfaces of the specimens heated in an oxidizing medium were oxidized, and those heated in a reducing medium were indistinguishable from the specimens of the first series. From these experiments it follows that graphitization during oxidation is greatly speeded up, but not the number of graphitic inclusions. This cannot be explained by attributing to oxidation an influence on the kinetics of graphitization, i.e. on an increase in the number of graphitic foci. Instead the experimental data seem to suggest that the effect of oxidation is an increase in the equilibrium concentration of vacancies on the surface of the zone, i.e. the diffusion of the surface ions of iron in the absence of oxide layers on the specimens.—L. H.

On the Methods of Investigating the Kinetics of the Graphitization of Cast Iron. Ya. V. Grechnyi and N. M. Danil'chenko. (*Lit. Proizv.*, 1957, (3), 20–22). [In Russian]. In the experiments described the influence of the cooling conditions after solidification on the graphitization process in cast iron was studied. 250-*g* batches of white iron with 2·52% C, 0·91% Si, 0·35% Mn, 0·041% S, 0·083% P, 0·05% Cr, and 0·029% Al were melted, superheated to various temperatures and cooled under various conditions. Microstructures obtained are illustrated. Significant effects on the number of centres of graphitization formed during annealing and on graphitization kinetics were observed over a wide range of conditions. Other factors considered include storage at room temperature and mechanical effects produced by cutting, grinding, etc.

Crystallization of Graphite on the Surface in Ni–C and Co–C Alloys. V. N. L'nyanoi. (*Izvest. Akad. Nauk, Otdel. Tekn.*, 1957, (8), 123–125). [In Russian]. Graphite separation on the surface of Ni–C (0·31% C) and Co–C (0·37% C) alloys has been studied and compared with that on type U12 steel (1·5% C). Photomicrographs showing microstructures are shown and discussed.—S. K.

On the Nature of the Light Zone in the Layer Adjoining the Friction Surface of Steels. N. N. Seleznev, I. E. Brainin, and P. I. Kuleshov. (*Vestnik Mashinostroenniya*, 1957, (3), 35–39). [In Russian]. The results of the experiments lead to the conclusions that, in the surface layers in the process of wear, the C breaks down first to the eutectic, i.e. to cementite of the lower layers. Parallel with the breaking down of the C, and under the influence of the temperature and of the internal stresses, coagulation of the various cementite elements occurs. The developing temperature in the surface layers and plastic deformation favour the formation of austenite, which however, due to the rapid cooling of most of the surface layer, changes into martensite. At the same time, the influence in depth of the temperature is not sufficient to promote dissolving of the coarser cementite grains, so that the structure of the light zone consists of martensite, the remaining austenite and the binding cementite.

Studies on the Rate of Separation of Primary Deoxidation Products in Iron Melts. W. A. Fischer and M. Wahlster. (*Arch. Eisenhütten.*, 1957, **28**, Oct., 601–609). A study has been made of the rate of separation of the deoxidation products following the addition of silicon to soft iron melts in a medium-frequency furnace. To determine the duration of separation of the primary products samples were taken at 1 or 2 min intervals after silicon addition, and the silicon and oxygen contents were measured. Non-metallic inclusions in the samples were isolated electrolytically.—L. J. L.

Structural Studies to Elucidate the Composition of Steels with Exceptionally High Contents of Alloying Materials Forming Extra Carbide. A. Schrader, A. Rose, L. Rademacher, and W. Pitsch. (*Arch. Eisenhütten.*, 1957, **28**, Aug., 461–468). The transformation, in the pearlite phase, of two steels (10 CrMo 9 10 and X 30 WCrV 9 3) has been studied using the electron microscope, electrochemical isolation, and X-ray diagrams from rotating crystals. The electron microscope alone enable: a decision as to the presence of a pre-eutectoid reaction to be made.—L. J. L.

Phase Conditions and Internal Crystallization Segregation in Fe–C–Si Alloys. Ya. N. Malinochka. (*Lit. Proizv.*, 1957, **3**, (10), 19–22). [In Russian]. The analyses of Fe–C–Si alloys of different compositions at varying temperatures have been made on the basis of horizontal and vertical sections of the composition diagram for the three elements. The vertical

sections can serve only for the qualitative determination of the phases. The results have shown that in low-carbon alloys and in alloys in which the crystallization ends with the peritectic transformation the incipient ferritic or austenitic crystals can originate directly during hardening in the internal crystallization liquation of the silicon, and that the concentration of silicon in the central regions of the dendritic formations within ferrite or austenite will be less than in the peripheral regions formed at the end of the hardening.

Formation of Graphite in Cast Iron During Crystallization and Thermal Treatment. K. P. Bunin. (*Lit. Proizv.*, 1957, **3**, (10), 15–19). [In Russian]. This very important problem is considered on the basis of a very complete reference list of English, American and Russian origin of nearly 70 investigators. It is considered under the headings of graphite formation during the crystallization of cast iron and after hardening.—L. H.

The Nature of the Carbide Phase of White Cast Iron. F. K. Tkachenko and V. F. Zubarev. (*Lit. Proizv.*, 1957, **3**, (11), 20–21). [In Russian]. Investigations are described by three methods: chemical, magnetic, and X-ray. The chemical results, obtained from powdered specimens of white cast iron are in full agreement with the structural formula of cementite and also with the results of other investigators. The magnetic measurements have established that the points of magnetic transformation for the specimens investigated are to be found in the region 200°–210°. The X-ray examination of powdered specimens has also shown complete identity with the above findings, and any small divergencies were found to be well within the margins of experimental error.—L. H.

The Influence of Additions on the Distribution of Sulphur in Steels. N. S. Kreshchanovskii and S. S. Kraskovskii. (*Lit. Proizv.*, 1957, **3**, (6), 22–26). [In Russian]. The purpose of this work was to establish the influence of various factors on the distribution of S on high-Cr casting steels of the type X11B2M, and this was studied by Bauman's method and through the microstructure.—L. H.

Distribution of Manganese in Iron Alloys. M. A. Krishtal and E. P. Rikman. (*Lit. Proizv.*, 1957, **3**, (7), 25–26). [In Russian]. The results of this work show that Mn is unevenly distributed between the austenite grains and their boundaries, and that these latter play an important role in the supply of Mn to the nodular graphite during the annealing of the cast iron.—L. H.

On the Solubility of Manganese in Cast Iron. A. F. Landa. (*Lit. Proizv.*, 1957, (8), 27–29). [In Russian]. Investigation of two marks of castings have shown that in both of them the duration of the eutectoid transformation during heating is practically equal. During the cooling, only the temperatures at the beginning of the transformation coincide. In manganese steels these temperatures are lower by 60°, but at the same time a small increase in volume has been observed.—L. H.

Change in the Fine Crystalline Structure of Austenitic Manganese Steel during Plastic Deformation. O. V. Bogorodskii and Ya. S. Umanskii. (*Izvest. Akad. Nauk SSSR, Seriya Fiz.*, 1956, **20**, (6), 614–620). [In Russian]. In the work described the structure and properties of a previously hot-rolled austenitic Mn-steel (1·14% C, 12·30% Mn, 0·32% Si, 0·006% S, 0·041% P) at various stages of cold deformation were determined, including the intragranular structure of the main solid solution, the hardness and the period of the austenite lattice. A rough evaluation of changes in ferromagnetic properties during static compression was made. It is concluded that increasing fineness of the mosaic-structure block is the main cause of the strengthening of Hadfield steel by cold deformation. The blocks become finer because of precipitation of carbides.—S. K.

The Phenomenon of "Sucking Away" of the Diffusion Layer of Chromided Steels at High Temperatures. G. N. Dubinin. (*Vestnik Mashin.*, 1954, (10), 84–87). [In Russian]. The experiments were carried out to determine the factors in "sucking away" independent of any external connections with the process, and were carried out in a high vacuum (10^{-5} mm) in ampoules in which the specimens were enclosed and subjected to various temperatures for 30, 60, and 120 h. The results of these experiments are given in detail in tables and graphs.—L. H.

Method of Control and Scale of Carbide Heterogeneity of High-Chromium Steels for Tools. A. G. Ivanov, E. V. Kruchinina, and L. G. Popova. (*Zavods. Lab.*, 1957, **23**, (9), 1088–1091). [In Russian]. The working out of a special scale for the control of carbide heterogeneity of high carbon and high chromium steels is described. It is based on many tests carried out at the "Electrostal'."

Distribution of Small Quantities of Carbon in Iron Alloys. A. S. Zav'yalov and B. I. Bruk. (*Doklady A.N.*, 1957, **115**, (1), 94–96). Cr, Ni, Mn, Si, and Mo iron alloys with introduced radioactive carbon ^{14}C, subjected to various types of thermal treatment, were studied by means of the method of autoradiography. The pattern of distribution of carbon in the metal, namely, uniform or concentrated along the grain boundaries, was shown to vary with the composition of the alloy and with its thermal history.—S. I. T.

Metallographic Investigation of the Carbide Phase in High Speed Steels. M. S. Chaadaeva. (*Zavodskaya Laboratoriya*, 1957, **23**, (7), 811–813). Metallographic analysis with the use of special reagents allows the determination of the composition of the carbide phase in steels. So, for instance, in steel P. 18 the main carbide phase consists of Fe_3W_3C. In steel 13–5 there are two phases, Fe_3W_3C and VC, with the latter predominating. In the eutectic of boron steel the carbide phase consists of the $Cr_{23}C_6$ type and Fe_3W_3C whilst the free carbide conforms to the type VC.—L. H.

The Role of Interfacial Energy during Solid State Phase Transformations. M. Hillert. (*Jernkont. Ann.*, 1957, **141**, (11), 757–789). [In English]. Pressure effects, nucleation, grain growth, and new phase formation are formulated. The nature of bainite is discussed and an inverse bainite postulated. Diffusion controlled processes are considered and the shape of the interface between growing pearlite and austenite is determined.

Contribution to the Study of the Transformation Without Diffusion $\gamma \rightarrow \alpha$ in Fe–C Alloys. B. Rotenstein, S. Caloghiru, and T. Teitel. (*Buletin Stiintific, Sectia Math. Fizica Acad. Rep. Pop. Rom.*, 1956, **8**, (1), 237–246). [In Rumanian]. The relatively stable range of the γ-phase in supercooled steels is an incubation period which determines the changes in the α phase formed by transformation without diffusion. The total quantities of α phase are smaller than those formed by sudden variations in temperature. The processes taking place at elevated temperatures Ar′ (500–450°) determine the relative growth of the α phase formed without diffusion. The incubation period corresponding to the zone Ar″ (400–200°) has no influence on these quantities. The determining factor of the transformation without diffusion is the temperature ($\gamma \rightarrow \alpha$) and not the tensions or stresses caused by the sudden chilling.—L. H.

The Formation of Stacking Faults in Austenite and Its Relation to Martensite. H. M. Otte. (*Acta Met.*, 1957, **5**, Nov., 614–627). An examination by X-ray and metallographic techniques on the systems Fe–Ni, Fe–Ni–Cr, Fe–Ni–C, and Fe–Mn–C after quenching and deformation suggests that Cr and Mn appreciably lower the stacking fault energy of austenite and Ni less so. C was difficult to evaluate. Stacking faults do not appear to be a source of nuclei in martensite.

Origin and Growth of σ-Phase in Purely Austenitic Weld Seams of Type 25-20 Steel. Yu. B. Malevskii and B. I. Medovar. (*Izvest. Akad. Nauk, Otdel. Tekn.*, 1957, (8), 84–88). [In Russian]. In the investigation described, electron-microscopy and X-ray structural analysis were used to study austenitic weld seams in type 25–20 steel, with special reference to the σ-phase. It was found that the dark areas on photomicrographs reflecting the dendritic structure of cast metal are regions in which secondary carbides of the type $Me_{23}C_6$ have accumulated. The growth of the σ-phase occurred in a periodic (growth-solution) manner, but this characteristic weakens with increasing duration of heating leading to uninterrupted growth which ceases only after the very prolonged action of high temperature. Local plastic deformation of the austenite led to a rapid $\gamma \rightarrow \sigma$ transformation.—S. K.

The Effect of Stresses on the Lattice Constant of Austenite. E. Houdremont and O. Krisement. (*Arch. Eisenhütten.*, 1957, **28**, Sept., 597–599). A critical comparison is made between the results of lattice constant determinations reported by various authors for the following: (1) γ-iron at room temperature, determined in Fe–Mn alloys; (2) γ-iron at room temperature, determined in Fe–Ni alloys. The extrapolation of the lattice constant of γ-iron to room temperature, the effect of dissolved carbon on the lattice constant of unstressed austenite, and the lattice constants of residual austenite (in the partially stressed state) are also discussed.—L. J. L.

The Effect of the Carbon Constant on Austenite Decomposition and its Partial Reactions. W. Jellinghaus. (*Arch. Eisenhütten.*, 1957, **28**, Aug., 469–481). In an earlier paper the author and E. Houdremont argued that, within the temperature range embracing the beginning of austenite decomposition, carbide formation, and then ferrite formation, the sequence of the partial reactions of austenite decomposition was determined by the carbon content, in that a low carbon content favoured the sequence of reactions initiating austenite decomposition with the formation of intermediate-stage ferrite, whereas a high carbon content favoured an initial segregation of carbide. The results of the tests on steels with low, medium, and high carbon contents, reported in the present paper, confirm this hypothesis.—L. J. L.

A New Method of Observing Austenite Grains, and Grain-growth Inhibition of Al-killed Steel. I. Relation between the Coarsening of Fine Grains of Al-killed Steel and the Solubility of AlN in γ-Iron. K. Endo and T. Otake. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 51–54). [In Japanese]. The method is particularly applicable for high temperatures. The specimen is heated in an inert atm., and evaporation occurs at most grain boundaries. As the result of evaporation and re-arrangement of surface atoms, characteristic crystal surfaces are exposed. The resistance to oxidation depends on the orientation, and hence oxygen admitted produces varying colours. The method was used to study the growth of low-carbon steel grains, and showed a strong correlation between grain-coarsening of Al-killed steel and the solution of AlN in γ-iron

The Effect of Silicon and Chromium on the Isothermal Eutectoid Transformation of Austenite in Spheroidal Cast Iron. S. Drápal. (*Hutn. Listy*, 1957, **12**, (10), 899–906). [In Czech]. Two series of cast irons were studied, comprising 8 different types. The Cr contents were 0·04, 0·2, 0·45, and 0·75% in each series, but the Si content was 2·2% in one and 2·7% in the other. The study showed that the transformation starts with the formation of ferrite, which begins to appear at austenite–graphite interfaces and at austenite grain boundaries at points close to graphite particles. The ferrite grains grow most rapidly in the vicinity of graphite grains. The ferrite zones formed in this manner later tend to coalesce into larger zones around graphite particles. The austenite is retained longest in the central parts of dendrites. In alloys low in Cr pearlite forms at a given stage of the transformation at a definite degree of supercooling. It nucleates predominantly at ferrite–austenite interfaces. The amount of pearlite present after completion of the transformation is greater the lower the transformation temperature. The curve representing the onset of pearlite formation and the curve characterising the end of the austenite transformation approach one another and eventually intersect. In the temperature range between this intersection and the lower eutectoid

temperature the austenite transforms only into ferrite and graphite. The rate of formation of austenite increases with decreasing temperature. An increase in the Si content was found to lead to a slight decrease in the incubation period, and to narrow the zone between the onset of the formation of ferrite and the beginning of the formation of pearlite. It also decreased the ferrite content present after the transformation and shifted the intercept of the curves of pearlite nucleation and the termination of the austenite transformation respectively to higher temperatures. Above certain Cr concentrations the curves no longer intersect, and the direct transformation of austenite becomes impossible; a mixture of ferrite and graphite results.—P. F.

Contribution to the Study of Transformations in 12% Mn Austenitic Steel. G. Collette, C. Crussard, A. Kohn, J. Plateau, G. Pomey, and M. Weisz. (*Rev. Mét.*, 1957, **54**, June, 433–486). The results of a comprehensive study using a variety of metallurgical techniques has enabled a complete understanding of the thermal decomposition of Hadfield type austenitic steel by isothermal quenching or tempering after hyperquenching at the surrounding temperature. Three decomposition structures were observed and their method of formation is described. The mechanism of cold working was examined and the high rate of hardening of the steels which exists throughout the whole deformation is explained. The results obtained suggest that the machining of Hadfield steels should not be slow, as is usually recommended, but very fast using ceramic type tools. Several tests carried out confirm this suggestion.—B. G. B.

Review of the Bainitic Transformation in Steels. L. Habraken. (*Inst. Encour. Rech. Sci. C.R.*, 1957, Nov., 5–122). **Concepts of the Bainite Transformation.** (11–22). A brief historical introduction and accounts of isothermal and non-isothermal transformation curves are given. **Study of the Bainite Transformation in Several Grades of Steel.** (23–94). TTT-curves and metallographic studies are extensively reported and illustrated, optical and electron micrographs are shown and compared. **Kinetics of the Bainite Transformation.** (95–118). Acicular and granular structures and the TTT-curves are discussed and mechanisms considered. Two mechanisms are found, for lower bainite and probainitic ferrite, coherent or incoherent growth of martensite and, for upper bainite, diffusion and the movement of lattice defects. Extension of the work of Krisement and Wever establishes the kinetics of upper bainite growth. (128 references).

The Surface Relief Effect due to Bainite Transformation, Observed under a Hot Stage Microscope. K. Tsuya and T. Mitsuhashi. (*Nippon Kinzoku*, 1956, **20**, Feb., 112–115). [In Japanese]. The progress of the bainite transformation is followed quantitatively by examining the surface distortions of various steels during thermal treatment. The relationship between the relief and etch structures is discussed.—K. E. J.

The Influence of Reduction Rate on the Destruction of the Carbide Lattice in Kh 12 and Kh 12 F1 Steels. S. I. Yulin and N. A. Stetsenko. (*Stal'*, 1957, (10), 948–950).

A Study of the Isothermal Transformations of Cu–Cr and Ni–Cr Cast Irons Containing About 0·5% Mo. A. de Sy and J. van Eeghem. (*Fonderie Belge*, 1957, May, 92–105). Detailed results are given of the isothermal transformation characteristics of 7 cast irons, one unalloyed, and 6 containing 0·5% Mo with different Cu and Ni contents. The results are presented as TTT curves and micrographs are given showing the as-cast structures of the 7 irons, and the isothermal transformation products obtained with the 0·5% Mo and the 0·25% Cr, 2% Cu, 0·5% Mo irons. The effect of Mo on the transformation characteristics is discussed with reference to previous work by the same authors. The application of the results to the production of acicular cast irons for cylinder blocks is briefly considered.

Phase Analysis of Iron–Nickel–Titanium Alloys. M. M. Shapiro and G. E. Levit-Gurevich. (*Zavodskaya Laboratoriya*, 1957, **23**, (8), 904). [In Russian]. The influence of temperature on the dispersion of intermetallic phase in these alloys, with varying amounts to Ti has been investigated. The results show that the precipitate consists of titanium and iron carbides and that the solutions contain Ni, Fe, and Ti. In the X-ray spectrogram, besides the carbides, only the lines of the hexagonal phase ϵ–Ni_3Ti occur and the lines of Fe_2Ti are absent. Hence one can assume that the iron passes with the phase Ni_3Ti and that in the alloy there is the intermetallic phase $(NiFe)_2Ti$.—L. H.

Phase Analysis of Chrome Nickel Titanium Steels with Intermetallic Hardening. N. I. Blok, N. F. Lashko, K. P. Sorokina, and F. F. Khimushin. (*Zavodskaya Laboratoriya*, 1957, **23**, (8), 901–903). [In Russian]. A new method is described of electrolytic separation of phases in alloys with intermetallic hardening. The type on which these experiments were made was EI 696 with the composition: 0·05% C, 19·45% Ni, 2·53% Ti, 11·65% Cr, 0·85% Al, 0·02% B. The effects of the pH of the solution, of the temperature, and of the current density on the disappearance of the intermetallic phase have been studied. The findings are tabulated.—L. H.

Abnormal Deformation of Steel during its Transformation. S. Tamaki. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 189–193). [In Japanese]. The hysteresis effect in the dilatation curve of heating and cooling steel obtained using a dilatometer attached by springs was studied. It is explained in terms of the large internal stresses produced by the volume change accompanying atomic rearrangement when carbides dissolve in, or separate from, austenite. If an external force, even small, is applied in one direction, the equilibrium is disturbed and deformation occurs during transformation.—K. E. J.

χ-phase (Fe_5C) in Tempering Carbon Steels. M. Okada and Y. Arata. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 186–189). [In English]. The existence of the χ-phase in the early part of the third stage of tempering quenched carbon steels is confirmed by means of magnetic analyses, graphitization tests and X-ray diffraction tests. (10 references).

Evidence for an "Inhomogeneity" of Carbon in an Austenitic Solid Solution. L. Colombier, J. Hochmann, and J. Bourrat. (*Compt. Rend.*, 1957, **245**, Sept. 30, 1135–1138). Intergranular corrosion of austenite suggested concentration of C at crystal boundaries. This has been tested by the use of ^{14}C in a steel with 12·8% Ni, 18% Cr, and 0·014% C prepared by cementation with activated $BaCO_3$ and the inhomogeneity demonstrated.

The Influence of the Annealing Temperature on the Form of the Graphitic Inclusions in Coke Cast Iron. G. I. Ivantsov. (*Liteinoe Proizv.*, 1957, (5), 25–26). [In Russian]. The form of graphitic inclusions defines the conditions of the diffusion of the matrix atoms from graphitization surfaces. These conditions depend on the chemical and physical homogeneity of the matrix and on the annealing temperature.—L. H.

The Relation Between the Lattice Constants of Austenite and the Temperature at which the Martensite Transformation Starts in Alloys of Iron and Carbon. V. N. Gridnev and V. I. Trefilov. (*Doklady A.N.*, 1957, **116**, (1), 60–62). On the basis of previously published data it is shown that the lattice dimension of austenite increases with increase of carbon content. Experiments carried out on 0·84% C steel with a martensite point of — 10° C quenched in water at 930–950° C and with a full austenite structure was held for 30 min at — 74° and later at — 183° at which temperature martensite was 80%. The corresponding changes in the lattice constant of austenite were 3·596, 3·589 and 3·584. This proves that during martensite transformation, austenite undergoes compression.—S. I. T.

The Structural Diagrams of Cast Iron. N. Hajto. (*Koh. Lapok*, 1957, **12**, Oct., 211–222, Öntödé). A comprehensive and critical review is given of the various kinds of cast iron structural diagrams.—P. K.

Investigation of a Metallic Compound Formed in Iron–Titanium Alloys. R. B. Golubtzova. (*Doklady A.N.*, 1958, **118**, (1), 89–91). Two samples of Fe–Ti alloys were subjected to anodic solution and precipitation of anodic powders which were subjected to X-ray analyses. The existence of a compound Fe_2Ti is confirmed. This compound has a hexagonal lattice with $a = 4{\cdot}769$ Å and $c = 7{\cdot}745$ Å.—S. I. T.

Kinetics of Superstructure Transformation of the Alloy Fe_2Al. V. E. Rode. (*Izvest. Akad. Nauk Seriya Fiz.*, 1957, **21**, (9), 1234–1238). The aim of this work was the investigation of the changes which occur in various physical parameters (electrical resistance, saturation magnetization, coercive force, effective anisotropy constant, lattice parameter) of Fe_2Al in the ordering process, and also to determine the degree of ordering of the alloy from the intensity of the superstructure lines on the X-ray diagrams.—S. K.

On the Ternary System Iron–Phosphorus–Zirconium. R. Vogel and R. Dobbener. (*Arch. Eisenhütt.*, 1958, **29**, Feb., 129–138). The phase diagram iron-iron phosphide FeP–Zr has been determined. Two hitherto unknown ternary phases with the formulæ FeZrP and Fe_4ZrP_2 were demonstrated. Both melt at temperatures above 1600° C.—L. J. L.

A Contribution to the System Iron (II)–Oxide–Iron (II)–Sulphide–Manganese (II)–Oxide–Manganese (II)–Sulphide. K. Geissler and E. J. Kohlmeyer. (*Arch. Eisenhütt.*, 1958, **29**, Jan., 57–63). Melts of 75–100 g were obtained and examined by thermo-magnetic methods and under the microscope. A description is given of the freezing process in the melts and of the interaction between the sulphides and oxides of the iron and manganese.—L. J. L.

CORROSION

General Aspects of Corrosion Theory. R. Piontelli. (*Corros. et Anticorros.*, 1957, **5**, Sept., 241–243). The author reviews the mathematical theory of corrosion, its prevention and control. He states that overvoltage, polarization and potential drop have to be included in considering corrosion processes.

Electrochemistry and Corrosion. M. Pourbaix. (*Corros. et Anticorros.*, 1957, **5**, Sept., 230–240). The theoretical and practical aspects of the electrochemistry and thermodynamics of corrosion are discussed and an apparatus for studying the kinetics of corrosion is described. (Oct., 286–293). The electrochemistry of iron and mild steel in bicarbonate solutions is discussed, also the influence of variations in pH on the potential and current density. The behaviour of 18/8 stainless steel in acetic acid/acetate solutions in presence and absence of NaCl is described, also the influence of chlorides and phosphates on the corrosion of iron and mild steel in bicarbonate solutions. A method for predicting the corrosion of metals and alloys at high temperatures and pressures is given, using extrapolation.—R. F.

Protective Linings for Steel Shipping Containers. L. J. Nowacki. (*Corrosion*, 1958, **14**, Feb., 100–102). Factors affecting the performance of linings on steel drums and similar containers include surface preparation, chemical and physical properties of the linings and application techniques. The alternative materials and methods are reviewed and quality tests outlined.—J. F. S.

Combined Methods of Increasing the Corrosion-Fatigue Strength of Steel. A. V. Ryabchenkov and V. F. Abramov. (*Vestnik Machin.*, 1955, (7), 54–57). Combined with electrolytic chromization and surface protection, three types of surface hardening were tried: shot peening, roller hardening and surface quenching. Surface strengthening combined with electrolytic zinc plating was also tried. Details of the experiments on various types of steel and different corrosion conditions are given.—S. I. T.

The Protection of Steel Equipment in the Chemical Industry Against Atmospheric Corrosion. 2. Protic. (*Zastita Mat.*, 1956, **4**, July, 241–242).

The Magnesium Anode for Cathodic Protection. T. Nœss and J. B. Østby. (*Tekn. Uke.*, 1958, **105**, May 1, 403–408). [In Norwegian]. The theory underlying the use of magnesium for cathodic protection and the application of magnesium and magnesium alloy electrodes for this purpose are discussed.—L. D. H.

Relation Between the Cathodic Protecting Current and the Intensity of Stray Currents in Buried Metallic Conductors. S. Minc and Z. Feldblum. (*Corros. et Anticorros.*, 1957, **5**, Nov., 308–314). A laboratory apparatus is described which simulates corrosion due to stray currents set up in buried pipes. This led to a formula relating stray currents to the minimum current necessary to give cathodic protection. Corrosion due to the soil is taken into account.—R. P.

Inhibition of the Corrosion of Buried Steel. T. Markovic, D. Zagar and N. Plavsic. (*Werk. Korr.*, 1958, **9**, Feb., 73–75). Results are given of laboratory tests lasting up to 30 days on the inhibition of the corrosion of buried steel by the addition of sodium chromate, nitrite, phosphate or benzoate to the soil. In some cases the corrosion was reduced to one-quarter of the value for non-inhibited soil.—J. C. H.

Some Findings on the Cathodic Protection of Buried Refinery Equipment. P. W. Sherwood. (*Werks. Korr.*, 1958, **9**, Feb., 82–86). A discussion of the protection of iron exposed to salt solutions containing oxygen by anodes of Mg, Zn or Al is given. Soil conditions, protective potentials and leakage currents should be determined before installation and these measurements are discussed. The position of the anodes, the choice of vertical or of horizontal anodes and some account of the costs of the installation are also considered.

Current and Potential Relations for the Cathodic Protection of Steel in Salt Water. W. J. Schwerdtfeger. (*J. Res. N.D.S.*, 1958, **60**, Mar., 153–159). Cold-rolled steel was exposed for 60 days to stagnant and aerated tap water containing 3% NaCl. Protection was most effective at a potential of $-0{\cdot}77$ v with reference to Standard Calomel, or $-0{\cdot}85$ v referred to $Cu/CuSO_4$.

Corrosion Prevention at the Stern Areas of H.M. Ships. J. C. Kingcome. (*Corros. Prev.*, 1957, **4**, Dec., 35–40). The author shows that, although considerable improvements have been made in protecting the stern areas of H.M. ships, the problem is not solved. The measures at present adopted, reinforced epoxy resin coatings and neoprene, are in general satisfactory, but corrosion troubles still occasionally occur. Some thought is being given to such methods of approach as combining cathodic protection with neoprene on rudders and shaft brackets. The best single contribution to the solution of the problem would be to fabricate the propeller of material of the plastic type but none, so far, has been able to withstand the severe conditions imposed.—L. E. W.

Spray Packaging and Marine Corrosion. (*Corros. Prev.*, 1957, **4**, Dec., 41–43). The "Cocoon" and "Koon Kover" processes used by R. A. Brand & Co. (Spray Packaging Division) for the protection of equipment at sea or of a laid-up vessel are briefly discussed.

Influence of Cathodic Polarisation on the Cavitation Resistance of Carbon Steel. L. A. Glikman and Yu. E. Zobachev. (*Metall. Obra. Met.*, 1956, (11), 50–54). Supplementary results obtained in the investigation of cavitation destruction by use of the magnetostriction vibrator under cathodic polarization show that this destruction occurs under two influences, mechanical and corrosive, and that the corrosive factor may be a direct consequence of the very appreciable electrochemical heterogeneity.—L. H.

Thermal Insulation and Corrosion Protection: A New Insulating Material Combining Both Properties. J. F. Williams and E. A. Blackwell. (*Corros. et Anticorros.*, 1957, **5**, Nov., 323–326). The use of naturally occurring gilsonites as thermal insulators and corrosion protectors is discussed. These gilsonites resemble asphalts. After packing in gilsonite, the pipes are heated, thus forming a plastic zone of gilsonite on the pipe, surrounded by a fritted zone. Some examples of applications are discussed.—R. P.

ANALYSIS

The Suitability in Practice of the Hydrochloric Acid Test for Distinguishing Rapidly Between Thomas and Open Hearth Steel. E. Rubo. (*Werkstattstechnik Maschinenbau*, 1958, **48**, Mar., 165–169). The use of the HCl test, in which the rise in temperature on dissolving turnings of Thomas Steel in dilute HCl is said to be greater than when taking similar turnings of O.H. steel into solution, is considered critically on the basis of experiments carried out by the author. It is concluded that the method has some merit in certain circumstances, in spite of the uncertainty of the results.—L. D. H.

Coulometric-Potentiometric Analysis in the Milligram Region. H. Lüdering. (*Arch. Eisenhütt.*, 1958, **29**, Mar., 173–178). A coulometric-potentiometric method of analysis is described, with a theoretical discussion, and applied to the determination of small amounts of Fe and Cr, either separately or when present together. The method is shown to be suitable for their determination in chromium carbides. A critical discussion follows.

Nephelometric Method of Determining Carbon in Alloys Containing More than 0·080% C. M. Tratapel. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, **4**, (10), 2085–2093). In the method described, the steel sample is oxidized at 1200° C in a steam of O_2 and the gas passed through a solution of barium hydroxide. The barium carbonate produced by the CO_2 from the carbon is maintained in suspension by a solution of gum arabic. The opacity of the suspension is measured and is proportional to the carbon present in the initial sample.

On the Determination of FeO, MnO and Dissolved Gases in Steel. M. Šícha. (*Hutn. Listy*, 1958, **13**, (2), 185–192). [In Czech]. In an attempt to separate MnO and FeO obtained by the electrolytic decomposition of steel, quantitative separation could not be secured. Also, in decomposing the residue obtained after electrolysis by chlorination *in vacuo*, considerable losses of the sample were registered. By means of fractional vacuum extraction of the sample with the addition of tin or graphite the joint amount of both oxides can be determined. The accuracy is, however, low because of the comparatively large volume of the blank. In gases evolved on heating pig iron and grey cast iron samples to 600° C *in vacuo* a certain amount of methane was demonstrated. This contained about 45% of the total hydrogen present in the samples, and accounts for the low diffusivity of hydrogen in grey cast irons.—P. F.

Rapid Hydrogen Analysis and Some Applications. W. A. Peifer. (*A.I.M.M.E. Elec. Furn. Steel Conf. Proc.*, 1956, **14**, 174–184). A vacuum system for rapid H_2 determination is outlined. Sampling is described. Trends in melting and processing are indicated.

Analysis of Gases in Steel by Heating *in Vacuo*. Yu. A. Klyachko, L. L. Kunin, E. M. Chistyakova and N. S. Larichev. (*Zavods. Lab.*, 1957, (12), 1410–1412). [In Russian]. An apparatus is shown which makes possible the separate determination of H_2 and moisture in steel by heating in a vacuum.—L. H.

Thermoelectric Method of Determining Carbon in Steels in the Course of the Heat. P. D. Korzh and A. P. Ershova. (*Zavods. Lab.*, 1958, **24**, (1), 41–43). A method is described of determining the carbon content of quenched, unkilled steel samples by changes in thermoelectric potential. Under controlled conditions, the latter was found to be directly proportional to the carbon content in plain carbon steels. The method of sampling and the measuring instrument used are described. Results obtained agreed with chemical checks to $\pm 0{\cdot}01\%$.—L. D. H.

The Determination of Tungsten in Steel Not Containing Niobium and Tantalum. Methods of Analysis Committee. (*J.I.S.I.*, 1958, **190**, Sept., 51–55). [This issue].

Application of Radioelements to the Study of the Ultra-Purification of Aluminium and Iron. P. Albert. (*Thèses. Faculté Sciences Université Paris*, 1956, 1–75). The results of a comprehensive investigation are reported. Various methods of preparing pure iron were studied. Samples were then irradiated in an atomic pile and the radioactivity of the impurities subsequently measured. The technique enables the analysis to be made at very low levels of impurity.—B. C. B.

INDUSTRIAL USES AND APPLICATIONS

Materials and Production of Steel Sleepers. W. Jäniche. (*Tech. Mitt.*, 1957, Dec., 306–312). The author discusses suitable specifications of steels used for railway sleepers and methods of production. The steel should be corrosion-resistant, easily hot- or cold-worked and the sleepers should be made to close dimensional specifications.—R. P.

Steels for Reinforced-Concrete Sleepers. W. Jäniche. (*Tech. Mitt.*, 1957, Dec., 313–318). The author discusses the properties of prestressed steels and reinforced concrete for the production of railway sleepers. He discusses suitable specifications and heat treatments. (10 references).—R. P.

The Choice of Steels for Gears and Their Heat Treatment. O. Patterman. (*Mét. Constr. Mécan.*, 1957, **89**, Apr., 337–344; May, 437–449; June, 549–559; July, 643–652). A review of the properties of steels used for gears is first presented. Tables are reproduced showing the analyses and properties of steels used in the U.S.A. and Europe for motor car gears. The choice of a particular steel is explained. The heat treatment of gears and the influence of heating time and tempering temperature on the properties of gears are considered. The influence of micrographic structure on machining output using carbide tools is reviewed. (44 references).—B. C. B.

Experience with the Introduction of Steel Substitutes in Heavy Lorries. P. A. Mishin. (*Metall. Obra. Met.*, 1956, (11), 30–33). During the last decade, the introduction of steels alloyed with Ti, Mn and Cr is replacing Ni and Mo alloys. The study was carried out to determine the technology of selecting suitable steels based on metallographic investigations, and on hardening, on static resistance tests of component parts (gears, shafts, cross-beams etc.) and on trials with lorries fitted with such spares. Full details concerning the steels used and their performance are given in the article.

Contribution to the Study of National Bearing Steels. M. Pujol Roig. (*Rev. Ciencia Apl.*, 1958, **12**, Jan.-Feb., 1–15). [In Spanish]. The special requirements of the high carbon–chromium steels for bearings are described and discussed with illustrations. The author underlines the need for inspection and points out the value of martempering these steels. It is shown that steels containing vanadium (i.e. 0·24%) behave better in quenching, have finer structures and greater tenacity than the vanadium-free equivalents. (20 references).

The Choice of Chemical Composition of Steels for Drilling Pipes Group D. R. Sejnoha. (*Hutnik.*, 1958, **8**, March, 78–85). An examination of the relationship between the mechanical properties of normalized drill pipes, class D, is given of which minimum mechanical properties are: proof stress 38 kg/mm², tensile stength 65 kg/mm², elongation 16%, reduction in area 40%, Notch impact strength 4·0 kg m/cm²; and composition 0·40–0·50% C, 0·50–0·80% Mn, 0·20–0·35% Si, not more than 0·045% P and S. Experiments were made with tubes of this composition and others with contents up to 1·1% Mn, and a statistical analysis of the results showed that the tensile strength and reduction in area were the most critical values for pipes in service. The greatest influence on mechanical properties was exerted by weight of melt and method of carrying out the test, which accounted for 47% of variations in tensile strength, and 59–69% in other values, whereas the composition accounted for only 22–29% of deviations. The effects of C, Mn and Si on tensile strength and of these and P on reduction in area were examined and relations were found for calculating these factors from composition, from which optimum C and Mn content was obtained. From an economic standpoint, analysis was made to establish standards for pipe

production taking into account rejects as well as costs of production.—M. T.

The Use of Heat-Resisting Steels in the Construction of High Temperature Heat Exchangers. (*Aciers Fins Spéc.*, 1958, March, 65–70). The various heat-resisting steels are listed together with a classification of the different types of heat exchanger. Examples are given of recent installations mentioning the main characteristics and the reasons for their choice.—A. G.

Friction Materials, Especially on an Iron-graphite Basis. E. Strobel. (*Technik*, 1957, **12**, Dec., 819–824). Following a survey of recent developments in materials for brake and other frictional uses, including sintered non-ferrous metals, a machine for testing materials is described and details are given of a material developed at the research institute of the COSID works in Dresden, East Germany consisting of a sintered iron compound with about 40–50% of graphite.—J. G. W.

Forging Alloys for Gas Turbine Discs and Blades. (*Aciers Fins Spéc.*, 1958, March, 22–25). The essential features of plant employed, fabrication techniques and inspection systems for the production of forged turbine discs and blades are discussed.—A. G.

Special Steels in the Atomic Industry. (*Aciers Fins Spéc.*, 1958, March, 40–45). Increasing quantities of special and stainless steels are required for nuclear plants. Uses discussed include reactor shells, thermal screens, control rods and plant for backing uranium ores.

How To Select a Resistance Heating Alloy. R. J. Fabian. (*Mat. Design Eng.*, 1958, **47**, Feb., 104–108). Ni–Cr–Fe and Fe–Cr–Al–Co are included.

HISTORICAL

Hindu Foundrymen Produced High Purity Iron Castings in 400 A.D. M. Singh. (*Mod. Castings*, 1958, **33**, Mar., 34). The early history of ironmaking in India is very briefly discussed with particular reference to the iron pillar at Qutab near Delhi.—B. C. W.

Ancient Tuscan Metallurgy. The Foundry of Follonica and the Lorena Family. B. Boni. (*Fonderia Ital.*, 1957, **6**, Nov., 421–430). [In Italian]. The history of the famous Tuscan foundry of Follonica is traced from the days of the Medici family to the year 1860. Many of the masterpieces of Florentine and indeed Tuscan art have their origins at Follonica. (10 references).—M. D. J. B.

The Ancient Britons Made Steel. M. G. Llewelyn. (*Brit. Steelmaker*, 1958, **24**, Jan., 15). The author briefly summarizes the evidence that shows that steel was made in very early times, even in the earliest part of the Iron Age.—G. F.

Metallurgy. R. J. Forbes. (*Metalen*, 1958, **13**, Jan. 15, 6–9; Jan. 28, 31; Feb. 15, 46–48; Feb. 28, 71–74; Mar. 15, 90–91; Mar. 31, 111–114; Apr. 15, 129–133). [In English]. A history of metallurgy in the ancient world, medieval times, and both ferrous and non-ferrous, is given.—(88 references).

Casting Iron Cannon. F. Evans. (*Found. Trade J.*, 1958, **104**, Feb. 6, 155–156). Methods of casting iron cannon in the 16th, 17th and 18th centuries are briefly described.—B. C. W.

The Centenary of Cowpers. L. Delville. (*Met. Corr. Ind.*, 1957, Oct., 397–405). The author reviews the history of the development of Cowper stoves and describes their operation.—R. F.

100 Years' Experience of the Open Hearth Process. F. Sommer. (*Giesserei*, 1958, **45**, Feb. 27, 117–122). An historical outline is given of the development of the O.H. process.—L. D. H.

A Contribution to the History of Steel Production and Treatment in Transylvania. S. Goldenberg and S. Kovacs. (*Met. Constr. Masini*, 1957, (11), 2–7; (12), 13–18). [In Rumanian]. The archaeological finds discovered in excavations include axes, swords, knives, bolts, padlocks etc. some dating from the Xth century. From microanalysis of some specimens deductions are made concerning the quality of the steel (which was very poor), the methods of its production and the heat treatment, which in some instances seems to point to some very skilful artisans.—L. H.

Johann Conrad Fischer, 1773–1854. E. N. Simons. (*Brit. Steel.*, 1958, **24**, Mar., 80–81, 85). Fischer's life and metallurgical achievements are reviewed. He was one of the foremost metallurgists of his day and was reponsible for the introduction of bulk cast crucible steel manufacture on the continent. He experimented with alloy additions, and his nickel steel was used for blades. He had wide commercial interests.—D. L. C. F.

Goran Fredrik Göransson. E. N. Simons. (*Brit. Steelmaker*, 1958. **24**, Jan., 16–17, 21). The author gives a brief account of the life and achievements of Goransson, the Swedish steelmaker. Only two years after Bessemer's announcement, Goransson succeeded in producing sound Bessemer steel. Later he founded the Sandvikens Jernverks.—G. F.

A Great French Metallurgist: Eugene Vicaire. (*Aciers Fins Spéc.*, 1957, Dec., 145–147). A short biography of E. Vicaire, including his outstanding achievements as a metallurgist. Some of his publications are mentioned.—R. F.

Takato Oshima (1826–1901) as Initiator of [Western Steel Metallurgy] in Japan. K. Mori. (*Tetsu-to-Hagane*, 1958, **44**, Feb., 170–180). [In Japanese].—K. E. J.

ECONOMICS AND STATISTICS

Post-War Achievements of Britain's Steel Industry. K. Jopp. (*Chem. Eng. Min. Rev.*, 1958, **50**, Jan. 15, 43–44). Statistical.

Productivity in the Iron and Steel Industry 1945–1956. M. D. J. Brisby. (*Engineer*, 1958, **205**, Mar. 21, 425–426). Statistical.

Steel Production May Be High in 1958. M. D. Howell. (*Ind. Heat.*, 1958, **25**, Jan., 80, 82). A brief statistical forecast.

Possibilities of Increased Steel Production in Poland. J. Zieba. (*Prz. Techn.*, 1957, **78**, Oct., 771–775). [In Polish]. In the next fifteen years the needs for steel in Poland are estimated to increase as follows: 1960–$7{\cdot}2 \times 10^6$ t; 1965—$9{\cdot}5 \times 10^6$ t; 1970—$12{\cdot}5 \times 10^6$ t. The author analyses the possibilities of increasing steel production in order to satisfy this demand. This can be achieved by modernization of old and construction of new steel works.

The Replacement of Steel Mill Plant and Equipment with Present Depreciation Reserves. W. T. Hogan. (*Iron Steel Eng.*, 1957, **34**, Dec., 79–84). The author discusses the problem of finance in the steel industry in the U.S.A. Although profits in recent years have been high, the present taxation laws make it difficult to set aside adequate sums to finance the new high capital cost plant and equipment needed to maintain productivity. It is suggested that tax laws should be changed to meet the new conditions.—M. D. J. B.

Some Problems Connected with the Planning of the Development of Steel Production in Poland. J. Dembowski. (*Hutnik*, 1957, **24**, Feb., 61–65). [In Polish]. Demand for and production of steel in Poland are analysed. The demand in 1970 will be 16×10^6 t, but the production will then reach only 13×10^6 t.

China's Fast-Growing Steel Industry. Chi Yen-Lang. (*Brit. Steelmaker.*, 1958, **24**, Jan., 10–12). Up to 1949, steel production in China totalled less than 10^6 t per annum. The author discusses the rapid growth of the industry to its present-day production level of 5×10^6 t, and outlines developments planned to raise this figure to 12×10^6 t per annum by 1962.—G. F.

Cyclical Rises and Declines in the Price of Steel Scrap. C. Hoskins. (*A.I.M.M.E. Elec. Furn. Steel Conf. Proc.*, 1956, **14**, 37–47). Statistical.

The Cup and Saucer Effect. F. R. Palmer. (*Reg. Tech. Meet. A.I.S.I.*, 1957, 651–659). Problems of the accumulation and liquidation of inventory (of steel product stocks) are discussed.

The General Cost Accounting Principles of the Iron and Steel Industry Issued in 1956 and Their Introduction in the Industry. C. E. Schulz. (*Stahl u. Eisen*, 1958, **78**, Apr. 17, 509–516). The author reviews critically the general cost accounting system.—T. G.

MISCELLANEOUS

The Education of Metallurgists in Moscow. J. Verö. (*Koh. Lapok*, 1957, **12**, March, 97–105). A comprehensive review is given of the development and state of education of metallurgists in Moscow. It is accomplished in five years after completing the usual middle school education. 15% of the study is politics, economy, foreign language and sport. The profession of metallurgy is divided in three groups: metallurgists, technologists and metal-physicists. The metallurgists are specialized as: furnace builders, pig-iron makers, steel makers, electro-steel makers and foundrymen.

Chlorination of Red Mud. J. Környei. (*Koh. Lapok*, 1957, **12**, Oct., 460–465). Hungarian experiments are reported in which samples of red mud were chlorinated at about 900° C for enriching them in TiO_2, separating metal oxides and separating the metal chlorides by fractional sublimation.—P. K.

The Actual Problems of the Technology of Manganese Production. J. Dembowski and A. Riesenkampf. (*Hutnik*, 1957, **24**, May, 192–197). [In Polish]. Heat, electric and chemical methods of obtaining Mn from low-grade ores are discussed. Recovering Mn from slags as an important source of supply for Polish industry is recommended and the need for research in this direction emphasized.

The Anodic Oxidation of Ferrochrome. B. S. Brčic, B. Mejač and B. Trpevska. (*Bull. Soc. Chim., Beograd*, 1957, **22**, (4), 233–243). [With German Summary].

Family Day Tours. R. A. Graney. (*Steel Proc.*, 1958, **44**, Feb., 84–86). An account of an industrial relations project in which visits to the steelworks of the Inland Steel Co. were arranged.

Errata. Vol. 187 (1957)

Sept. p. 74, col. 1, line 30.
For "T. M. Norén" *read* "S. M. Norén."
Nov. p. 253, col. 1, line 37.
For "Zenner" *read* "Zeuner."
p. 256, col. 1, line 20.
For "I. M. Goncharov" *read* "I. N. Goncharov."
p. 263, col. 1, line 2 from bottom.
For "Odeka" *read* "Odaka."
p. 269, col. 1, line 22 from bottom.
For "Cotterell" *read* "Cottrell."
p. 271, col. 2, line 24.
For "Tamoue" *read* "Tanoue."
Dec. p. 349, col. 2, line 2.
For "B. D. Nijhawan" *read* "B. R. Nijhawan."
p. 359, col. 1, line 32.
For "Matsumoto" *read* "Masumoto."
p. 377, col. 2, line 17 from bottom.
For "Chatterjee" *read* "Chatterjea."

BOOK NOTICES

ALLEN, G. C. "*Japan's Economic Recovery.*" $8\frac{3}{4} \times 5\frac{1}{2}$ in., pp. xi + 215. Oxford, 1958: Oxford University Press. (Price 25*s.*).

JONES, F. C., "*Hokkaido, its Present State of Development and Future Prospects.*" $8\frac{1}{4} \times 5\frac{1}{2}$ in., pp. viii + 146. Illustrated. Oxford, 1958: Oxford University Press. (Price 21*s.*).

In different ways these books enable one to appreciate the tremendous problems which face the Japanese today and their achievements in meeting them. Dr. Jones discusses the present and future of Japan's comparatively underdeveloped northernmost island which, thanks to its rich coalfields and considerable (for Japan) iron-ore deposits, has become a fairly important centre of the iron and steel industry. Professor Allen surveys Japan's remarkable post-war resurgence and devotes part of a chapter to the industry. Both books are issued under the auspices of the Royal Institute of International affairs.—M. L. P.

BRITISH STEEL CASTINGS RESEARCH ASSOCIATION. "*A Practical Guide to the Design of Steel Castings.*" 10½ × 8 in., pp. (ii) + 52. Illustrated. Sheffield, 1958: The Association. (Price 12*s.* 6*d.*).

The British Steel Castings Research Association has published this excellently produced and moderately priced English translation of the French "Guide Pratique du Tracé des Pièces en Acier Moulé," issued previously under the auspices of the Centre Technique des Industries de la Fonderie. The original French title and date of publication do not appear but efforts have been made through most of the Guide to give British equivalents and approximations for metric measurements and values. This Guide should be a valuable addition to the steel foundry and drawing office library. The arrangement is logical and the subjects dealt with include Properties of Cast Steel (the Association will shortly publish a detailed comparison between the French and British specifications for steel castings), Foundry Defects Attributable to Bad Design and Design Rules both Dependent and Independent of the Direction of Moulding and Pouring. There are 121 figures clearly drawn and printed.—M. L. P.

COOK, P. M. and A. W. MCCRUM. "*The Calculation of Load and Torque in Hot Flat Rolling.*" 12½ × 12½ in., pp. 109. Illustrated. London, 1958: British Iron and Steel Research Association. (Price 65*s.*).

This is a most useful publication, allowing as it does the estimation of roll force and torque during the hot flat rolling of a variety of steels. The pages are 12 in. square, substantial, and highly glazed, and the reproduction is clear and accurate. Pages 14 to 109 give the relevant graphs for the following steels:—

Low, medium and high carbon: En 16, 25, 31, 40, 45, 52; 18/8 stainless, 2½% C/13% Cr, and 18/4/1 high speed. These graphs are preceded by a short introduction and two appendices in which is outlined the theory on which the method is based.

The theory used is that put forward by R. B. Sims in *Proc. Inst. Mech. Engrs.*, 1954, 168, (6), 191–200, which, as has been demonstrated in recent researches, gives good agreement with experiment. The authors rewrite Sims's basic equations in the form:—

$$P = R'J_pC_p \quad \text{(Roll Force)}$$
$$G = 2RR'J_gC_g \quad \text{(Roll Torque)}$$

In these equations C_p and C_g are dependent merely on the geometry of the roll pass, and are plotted against $\frac{R'}{h}$ for the range of reductions normally encountered in practice. (R' is the deformed roll radius and h is the final stock thickness). J_p and J_g are functions of reduction and mean yield strength through the pass, this latter being a function of mean strain rate. Thus J_p and J_g can be plotted as functions of reduction and mean strain rate for any particular material, and these constitute the graphs for the twelve steels already mentioned above.

To determine the values of mean yield strength as a function of mean strain rate the authors have used results obtained in uniaxial compression tests on the high speed 'cam plastometer' housed in the B.I.S.R.A. laboratories. It is gratifying to note that the authors have recognised the fundamental difference between the uniaxial compression test and the plane strain compression occurring in rolling, and have adjusted this data accordingly, on the assumption that the material considered obeys the von Mises criterion of plastic flow.—J. M. ALEXANDER.

DEUTSCHE GESELLSCHAFT FÜR CHEMISCHES APPARATEWESEN E.V. "*Dechema-Werkstoffe-Tabelle.*" "*Chemische Bestandigkeit der Werkstoffe.*" 3. Bearb. 12 × 8½ in., loose-leaf 5, 6 and 7 Lieferungen. 100, 89 and 103 sheets. Weinheim/Bergstrasse. (1955–1957): Verlag (Chemie G.m.b.H. (Price DM 0.30 per sheet).

Since part 4 of this collection was received (see *J.I.S.I.*, 1955, 181, 109), three further sections have appeared, covering *Cellosolves* (glycol monoethers) to *Chlorwasserstoff* (hydrochloric acid), *Chlorxylenole* to *Diglycolsaure*, and *Dihydroxydiphenylsulfon* to *Fluorwasserstoff* (hydrofluoric acid). The list of substances whose reactions to them are given remains the same, the accompanying notes are as useful as in the earlier parts.—J. P. S.

"*Electronic Engineer's Reference Book.*" Science Editor, L. E. C. Hughes with a foreword by Percy Dunsheath. 7½ × 5 in., pp. 1311. Illustrated. London, 1958: Heywood & Co., Ltd. (Price 84*s.*).

The broad conception of this handbook is excellent, since there is a shortage of standard works covering this whole field. Much has been published on such branches of the subject as radio-communications, but a reference book of 1200 pages compiled by over 50 specialists can be of great value to the engineer wishing to broaden his knowledge of this rapidly expanding technology. It is a difficult book to review, since few electronic engineers can claim complete familiarity with all the topics covered. It is not easy, therefore, to apply uniform standards of judgment throughout.

The text reads easily and the presentation of diagrams is of a high standard. The decimal sequence adopted for numbering paragraphs, diagrams and tables has many advantages in clarity, etc. The pleasing effect is marred, however, by the inclusion in the text pages of a considerable number of full page advertisements which should preferably be at one end of the book.

The choice of material and its arrangement seem rather arbitrary in places, and there are some surprising inclusions. For example, lubrication and mechanical spring design belong more to a text book of mechanical engineering, while a section on colour television is included in spite of an editorial note in the preface that radio and television would be excluded. In section 956 one must agree with the author that "Abbreviations are a menace" and deplore the fact that it is considered necessary to tabulate 32 pages of them. Finally, in chapter 21 on infra-red technology, data are given relating to type M.1 Infra-red detectors and type ON20 heat-resisting glass, both now out of production. This is probably an indication of the inevitable time lag between the preparation of a manuscript and final publication of a book. However, chapters on such topics as valves and transistors, sound measurement, electronic musical instruments and electronic computers are very properly the meat of this book and are well handled.

A number of mistakes has occurred. For example, paragraph 617 is headed "Flaw Detectors" in a chapter devoted to "Ultrasonics," but in fact describes the magnetic iron flaw detector. No mention is made of the well established ultrasonic flaw detector. In paragraph 311 is found the statement "When $6{\cdot}242 \times 10^{18}$ electrons per second move across a reference *point* . . .," while another otherwise excellent section 421 containing valve data tables is spoiled by table 4215 in which power rectifiers and signal diodes are not shown separately. In this table, too, another credits the DA90 valve with a current rating of 0·5 amps instead of 0·5 milliamps.

In conclusion then, this book must be regarded as a useful contribution to a reference shelf. Its value would, however, have been enhanced by more thorough editing. It is thought, too, that a wider selection of references in the bibliography might well have been given.—B. O. SMITH.

GAYDON, A. G., "*The Spectroscopy of Flames,*" 10 × 6½ in., pp. ix + 279. Illustrated. London, 1957: Chapman & Hall, Ltd. (Price 50*s.*).

Although it forms part of chemical engineering studies at Imperial College, the work of Dr. Gaydon and his colleagues on flames is at a very "pure" level. The present volume shows little sign of contamination by the immediate needs of engineers. This is not in the slightest to decry its outstanding contribution—with critical references to 464 other publications—to the fundamental understanding of the processes within flames. Dr. Gaydon's monograph on "Spectroscopy and Combustion Theory" first appeared in 1942. Later research has made necessary not a revision but a completely new effort.

Analysis of the radiation is a means of examining events without interference with the flame itself. In this it has an advantage over chemical sampling. Its disadvantage is that it throws undue emphasis on a relatively small number of electronically excited radicals. The visible and near ultra-violet emission seldom exceeds 0·4% of the energy released by the combustion processes. Nevertheless spectroscopic evidence makes a major contribution to the understanding of flames.

All the work described here has been carried out on small laboratory flames. Furnace flames as such are treated in three-quarters of a page, although reference and credit is given to Thring's book and the reports of the International Flame Radiation Research Committee. Apparently these flames show strong continuous spectra from hot solid particles and are spectroscopically of little interest. Only the final chapter on flame spectrophotometry is likely to be of direct applied value in the iron and steel industry. In this, guidance is given on the choice of a flame type, the burner and atomiser system, recording methods and problems arising from interference by one element with the determination of another.

This book should be of service mainly to those engaged in research in the field of chemical mechanisms, excitation processes, energy distributions and allied basic properties of flames.—I. BERKOVITCH.

"*Gmelins Handbuch der Anorganischen Chemie.*" 8 völlig neu bearb. Aufl. System Nr. 28: "*Calcium.*" Teil A, Leferung 2. "Vorkommen. Element. Legierungen." Teil B, Lieferung 2. "Verbindungen bis Ditnionit." 10 × 6¾ in., pp. xii + 420, and xvi + 392. Illustrated. Weinheim/Bergstrasse, 1957: Verlag Chemie G.m.b.H. (Price DM. 232 and DM 219).

The arrangement of these two volumes follows the usual Gmelin course, of logical arrangement, e.g., from the occurrence of the element in the cosmos, through a country-by-country enumeration of the deposits of calcium minerals to a similar exhaustive treatment of calcium compounds, beginning with CaH. At all stages, copious references are given though, as it is explained, only up to the end of 1949. A few later ones have, perhaps luckily, crept in, but it seems regrettable that the extreme thoroughness of this compilation should stand in the way of more rapid publication.—J. P. S.

"*Hydraulic Handbook.*" First edition. Compiled by the Editors of "Hydraulic Power Transmission." 10 × 7½ in., pp. viii + 764. Illustrated. Morden, 1958: Trade and Technical Press Ltd. (Price 90*s.*).

This extremely well illustrated volume begins with a section of 106 pages on the principles of hydraulics demonstrated by innumerable devices which show the practical application of these principles in pumps, power-assisted steering, servo-motors and so on. It passes on to more general applications, including a section of some 16 pages on hydraulic presses, and concludes with a variety of useful tables nomograms, charts of symbols, a glossary, and the inevitable Buyers' Guide and Index to Advertisers. To all engineers who operate hydraulic machinery this should be a valuable book.—J. P. S.

PARR, J. G. "*Man, Metals and Modern Magic.*" 8 × 5½ in., pp. 238. Illustrated. Cleveland, 1958: American Society for Metals. (Price $2.29).

This book conceals a lot of useful, and

some inaccurate, information behind a meretricious title. It begins slightly before Neanderthal man and follows the course of the discovery and utilization of metals up to the present day. The author gives an excellent account of the development of metallurgy in the Bronze and Iron Ages, its decline in the Dark Ages and its revival during the Renaissance.

From the 17th century, it becomes possible to link processes to personalities—Dud Dudley, Huntsman, Cort, Neilson, Bessemer, Siemens and then, unfortunately, errors have crept in. Dudley did not invent, nor ever partially succeed in the use of coal in iron smelting (p. 115); Abraham Darby found coke in use for malt drying and used it in iron-smelting in 1709, not 1715 (p. 116); There was no such person as Andrew Yarborough (p. 123)—his name was Yarranton. It is simply not true that it took Huntsman from 1740 to 1770 to perfect the crucible process (p. 121); the Walkers were using it successfully by 1750. Sheffield water is no better for quenching than that of other rivers than the Don (*ibid.*).

The description of Bessemer's progress towards the pneumatic process is at fault (p. 160) in that Bessemer discovered that the oxidation of iron and carbon gave out heat, enough to keep the charge molten, quite by chance. Nor is it true that he called the product "semi-steel" (p. 161)—at first he called it "malleable iron; and whatever William Kelly produced in 1847 (p. 170) it was not by any means all and always malleable. The Siemens brothers did not protect the regenerative furnace in 1861 (p. 169) but in 1856; and the first units were coke, not gas-fired. Moreover, the first arc furnace was made, if not by Humphrey Davy in 1810, then by Despretz in 1849; Siemens first applied it to steel-making (p. 174).

Historical bases laid—in the general way, accurately enough for his purpose—the author passes on to a popular, readable account of the "Modern" metals and their uses; Uranium and plutonium, of course, and titanium, gallium, caesium, and so on, and to a brief chapter on fabrication and to some reflections on modern metallurgical science. His final conclusion is that in an age to come with metals worked out and slowly and uselessly going back to the earth they came from, man may well again, as at the beginning, cook in earthenware pots, plough with flints and kill with stones.—J. P. S.

REIFFE, EMIL (Editor). "*Pressenotizen zum 400 Todestag von Georg Agricola* 1494–1555." 12 × 9¼ in., pp. 63. Illustrated. Schaffhausen, 1956: Eisenbibliolhek. (No price).

This remarkable volume, prepared by the famous "Iron Library" at Schaffhausen comprises all the articles in the Swiss and German press commemorating the 400th anniversary of the death of the great Agricola; these articles are cut from the periodicals themselves, mounted on very thick paper and bound in cloth. Agricola is best known in England as the author of "De Re Metallica," translated by the Hoovers in 1912, but his fellow German-speakers and countrymen find him a far more catholic and appealing figure. The paper "Vaterland" contributes an article "Humanism and the Catholic Church in the Life of Georg Agricola" and the Berne scientific journal "Der Ornithologische Beobachter" one on "Georg Agricola and the Bird World." This latter describes "De Animantibus Subterraneis," often bound with "De Re Metallica" but not translated by the Hoovers. In it, Agricola discusses birds, and many other creatures which live in caves and holes, or spend part of their lives there: he is able, therefore, to consider bats, otters, porcupines and kingfishers as well as the good and bad spirits of the mines. The remaining articles are devoted to the better known Agricola, geologist, mineralogist and miner.—J. P. S.

SCOTT, J. D. "*Siemens Brothers* 1858–1958." With a foreword by Viscount Chandos, P.C., D.S.O., M.C. 10 in. × 6½ in., pp. 279. London, 1958: Weidenfeld and Nicolson. (Price 35*s.*)

The history of the great electrical firm which, founded by Werner and Wilhelm Siemens and J. G. Halske, as Siemens and Halske, became Siemens Brothers and Co., Ltd., and is now part of Siemens Edison Swan, Ltd., a member of the Associated Electrical Industries group, in interesting and complicated, both on the technical and the commercial sides. The ramifications of the company, particularly in its German connection which led to some undeserved attention from the Custodian of Enemy Property in two wars, were as widespread and various as the cable networks and electrical apparatus for which their name is so well known. In this careful account of the progress of the firm from the arrival in 1843 of the first of the brothers, Carl Wilhelm—later Sir William, fifth President of the Iron and Steel Institute—to the present day, there is little of direct connection with the iron and steel industry; there are, indeed, only six references to the regenerative furnace and open-hearth steelmaking, and it is made clear that Carl Wilhelm's experiments, though carried out nominally at his own expense were, for a time at least, a financial drag on the young electrical enterprise.

Nevertheless, the open hearth process was developed, and the firm survived; the former because of William's determination, the latter because of the energy and enthusiasm of the several Siemens brothers, their relations and their associates.—J. P. S.

SCOTT, W. H., *et al.* "*Technical Change and Industrial Relations. A Study of the Relations between Technical Change and the Social Structure of a Large Steelworks.*" The University of Liverpool, Department of Social Science. Social Research Series. 8¼ × 5½ in., pp. [ii] + 336. Illustrated. Liverpool, 1956: The University Press. (Price 17*s.* 6*d.*).

WALKER, CHARLES R. "*Toward the Automatic Factory. A Case Study of Men and Machines.*" 8¼ × 5½ in., pp. xxii + 232. Illustrated. New Haven. London, 1957: Yale University Press; Oxford University Press. (Price 30*s.*).

"*Men, Steel and Technical Change.*" By the Industrial Research Section, Dept. of Social Science, University of Liverpool. Problems of Progress in Industry—I. 8½ × 5½ in., pp. 36. Illustrated. London, 1957: H.M.S.O. (Price 2*s.*).

"Technical Change and Industrial Relations" is a detailed study made at Liverpool University of the introduction of a continuous strip mill and the replacement of older open hearth shops by a larger, more modern shop. The parts played both by steel industry union traditions and by management wisdom in ensuring the smooth introduction of these changes are well displayed. Valuable insight is offered into several important aspects of steel industry industrial relations—the importance of seniority expectations as well as wages, the social impact of continuous working, the new relationships in modern plant between craftsmen and process workers. Changes in management structure are also examined. A detailed case study is devoted to the attitudes of melters in the new shop. The general conclusions seem rather superficial. Perhaps there has been too much emphasis on the practical implications of the study, which seem for the most part very obvious, instead of attempting more generalisations relevant to theoretical research into human behaviour, to which the book is an important contribution.

"Toward the Automatic Factory" is exclusively a case study of the human problems involved in the establishment of the first semi-automatic tube mill in America alongside older tube mills. It embraces problems of recruitment and training (including seniority issues), the changed balance of physical and psychological demands, the introduction of incentives, and the relationship between the conquest of technical difficulties and the creation of a high-morale crew working as an efficient team. The study omits some important social influences which must have been significant but the conclusions are more critically analytical than those of the Liverpool University study.

"Men, Steel and Technical Change" is a pamphlet summary of the Liverpool University Study. Human behaviour is so complex a series of contradictory phenomena, that few of the generalizations in this pamphlet are really meaningful in their own right. The real value of the studies reviewed here lies in their contribution to an overall understanding of human behaviour in industry. Much of this understanding seems lost in the pamphlet summary.—K. D. M. DAUNCEY.

SOUBDILLON, ANDRÉ. "*Traitement Thermique des Aciers de Construction.*" Deuxième édition entièrement revue et augmentée. 10½ × 9½ in., pp. 361. Illustrated. Paris, 1957: Institut Supérieur des Matériaux et de la Construction Mécanique; Editions de la *Revue d'Optique.*

This book, which is a second edition, covers the various aspects of the heat treatment of steel in a very satisfactory manner. The preliminary chapters deal with the basic principles and there is a reasonable balance between the proportion of introductory matter and more advanced theory. There is a discussion of hardenability and the various methods of measurement. This is followed by several chapters dealing with the effect of cooling rate and alloy content on the properties of the various types of steels. It is noteworthy that the composition of the steel under discussion is always given and this makes these chapters more acceptable to any reader unfamiliar with French specifications and trade names. There is a detailed description of the surface treatments which may be applied to steels, carburizing, nitriding, etc. and also a short section on induction heating. The effects of the various types of furnace atmospheres on steel are described, together with methods of atmosphere control. Finally there is a short section on the examination of heat treated components for defects.

The book contains a large number of line drawings and at the end of each chapter there is a generous list of references for further reading. There is no index but the list of contents is fairly detailed. It has been printed by a photographic technique on rather low grade paper and is bound in paper backs, probably to keep the cost of what would otherwise be a very bulky book as low as possible and within reach of the students and those concerned in the practice of heat treatment, to whom it will be most useful.—G. LUCAS.

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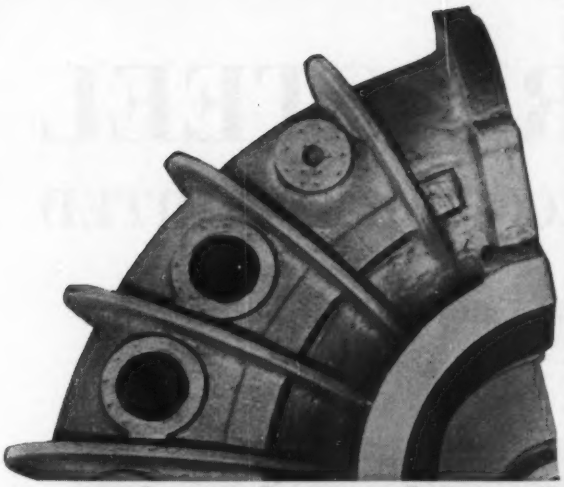

Half gas circulator casing cast in steel and machined for C. A. Parsons & Co. Ltd. for Nuclear Power Station, Calder Hall. Weight as cast 35 tons. Sectional thickness max 7" min 1½". Reproduced by permission of C. A. Parsons & Co. Ltd.

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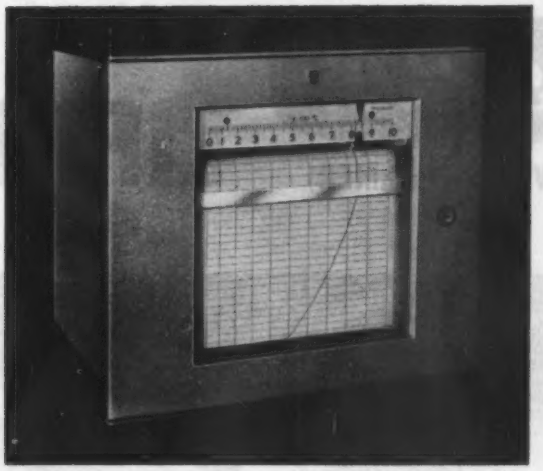

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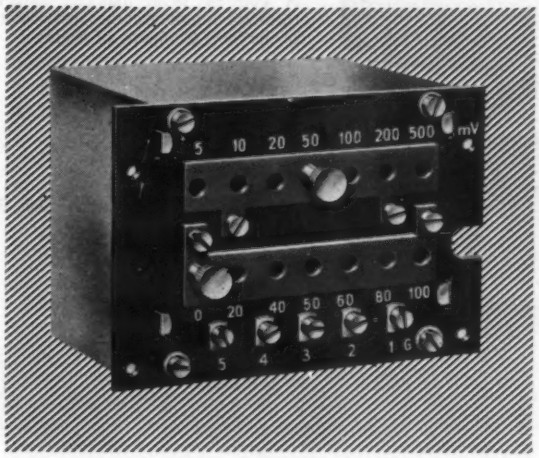

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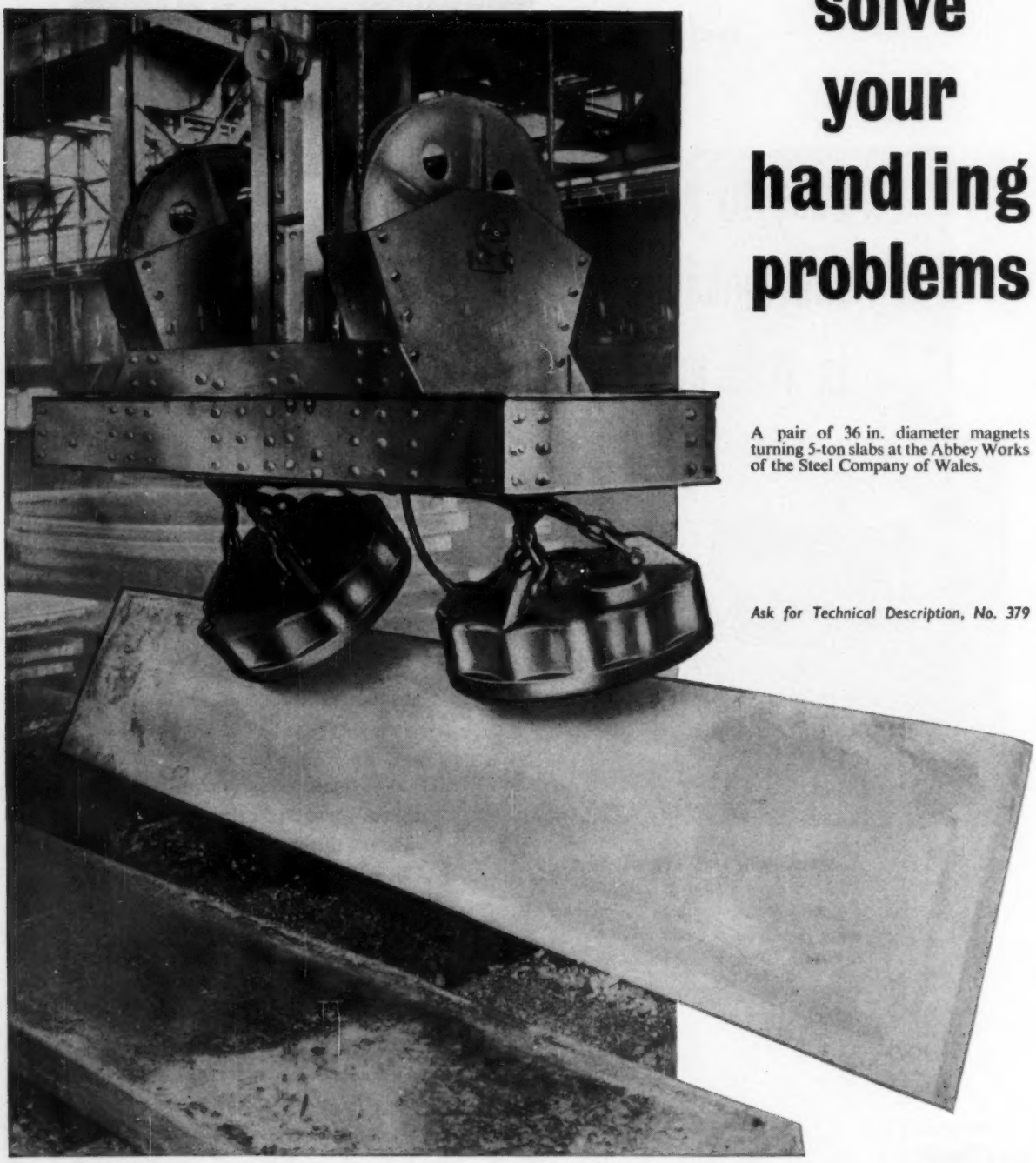

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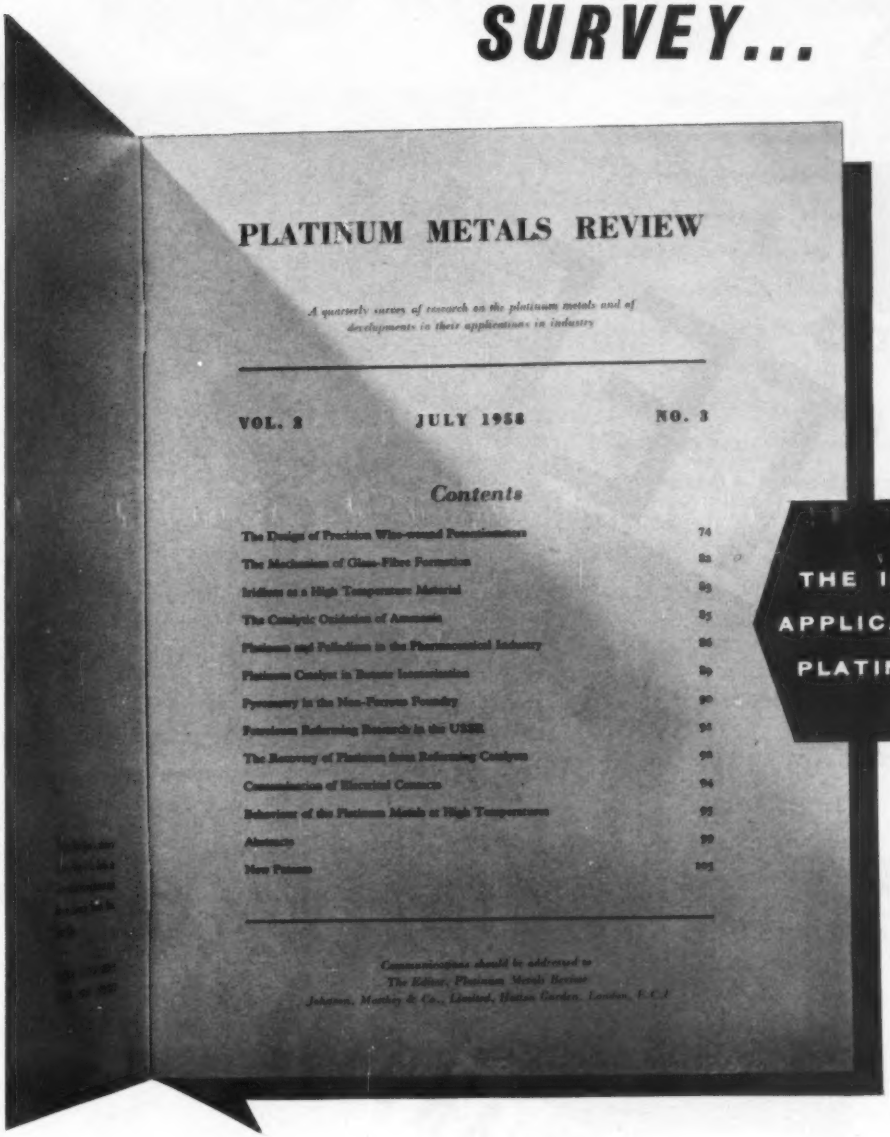
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VOL. 2 JULY 1958 NO. 3
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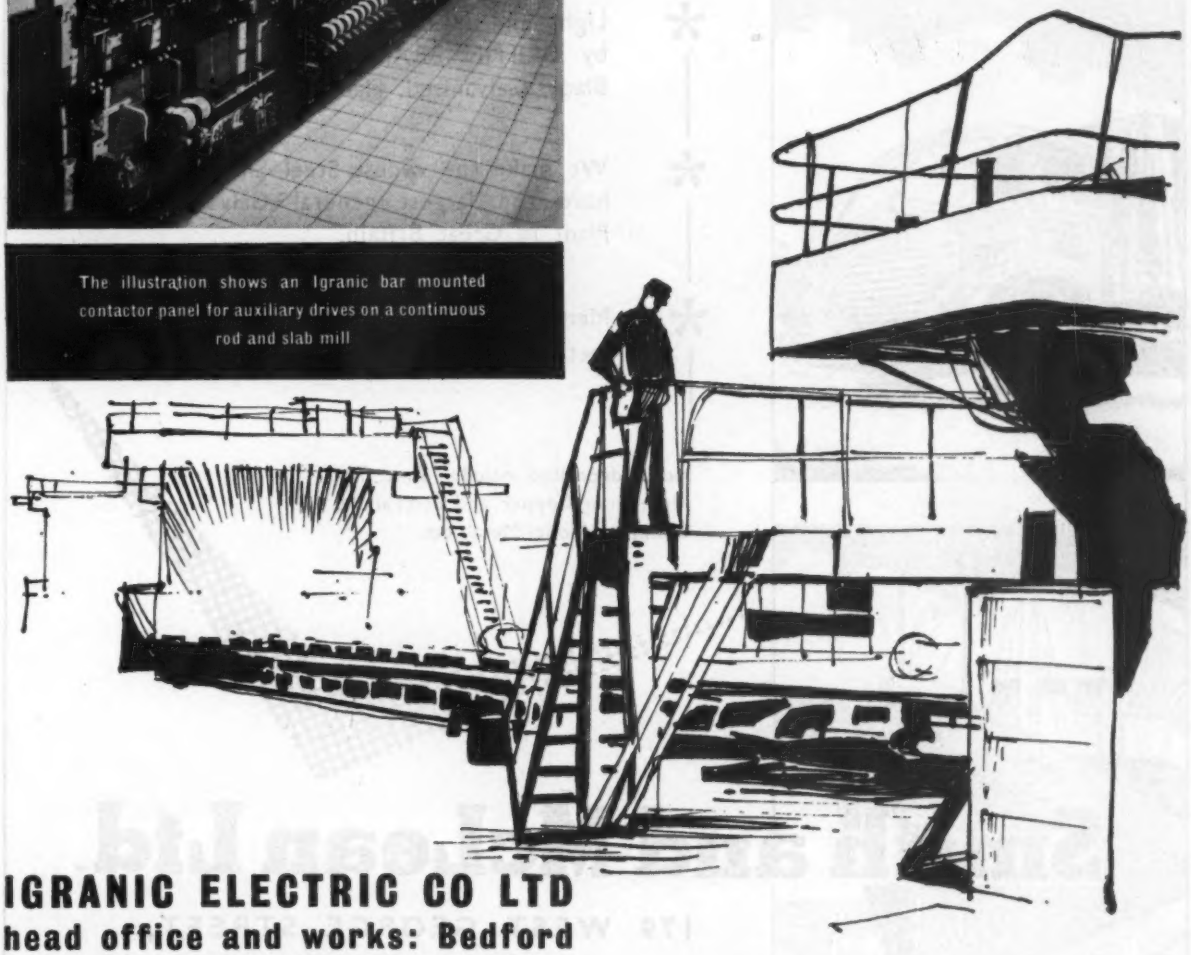

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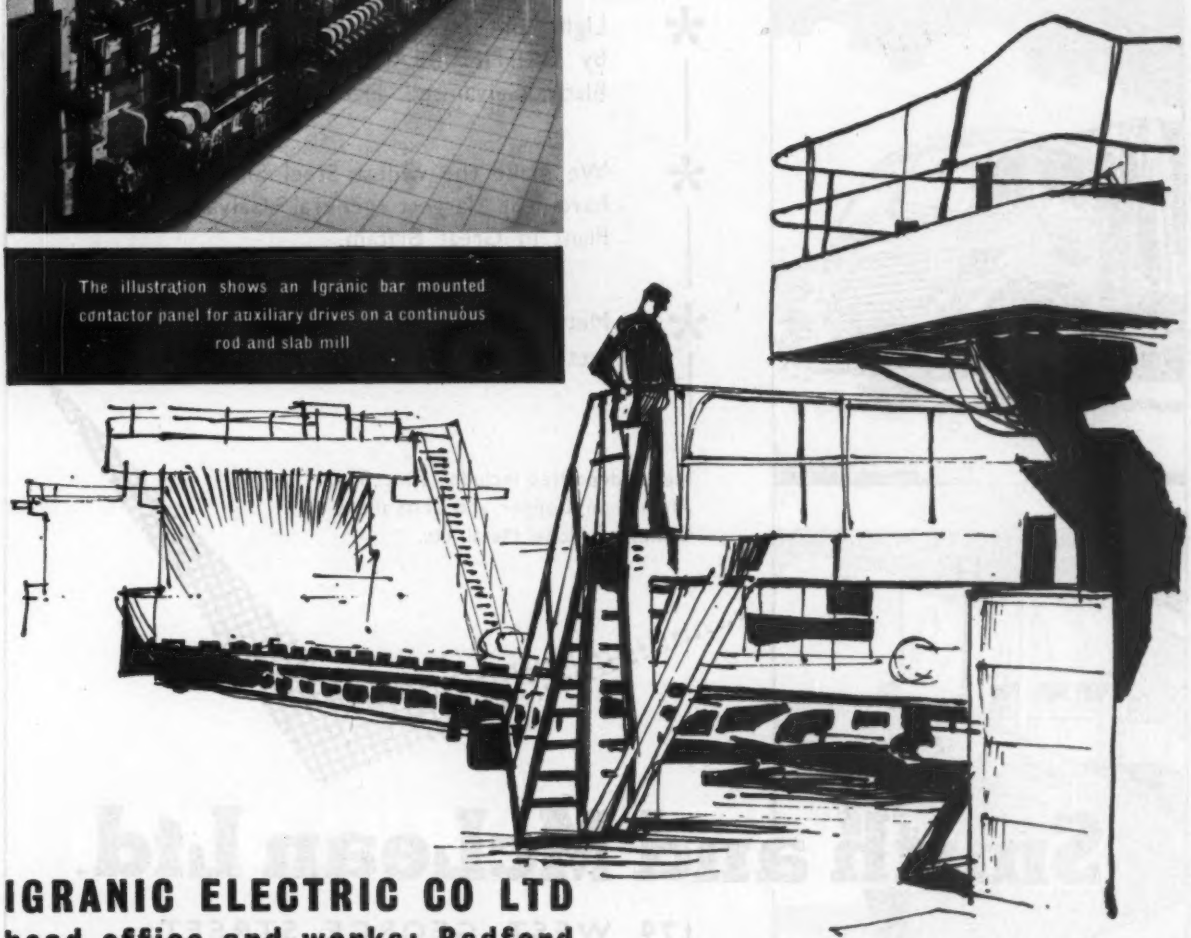

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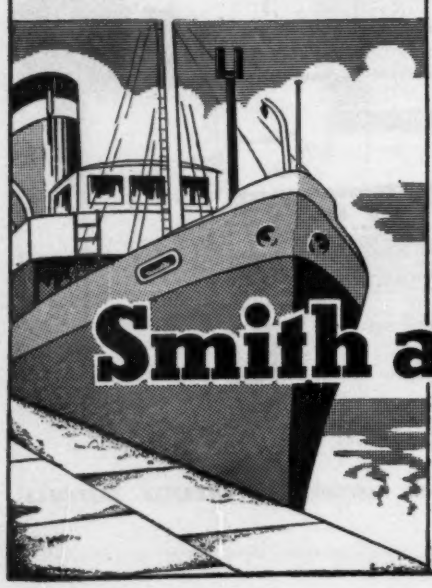

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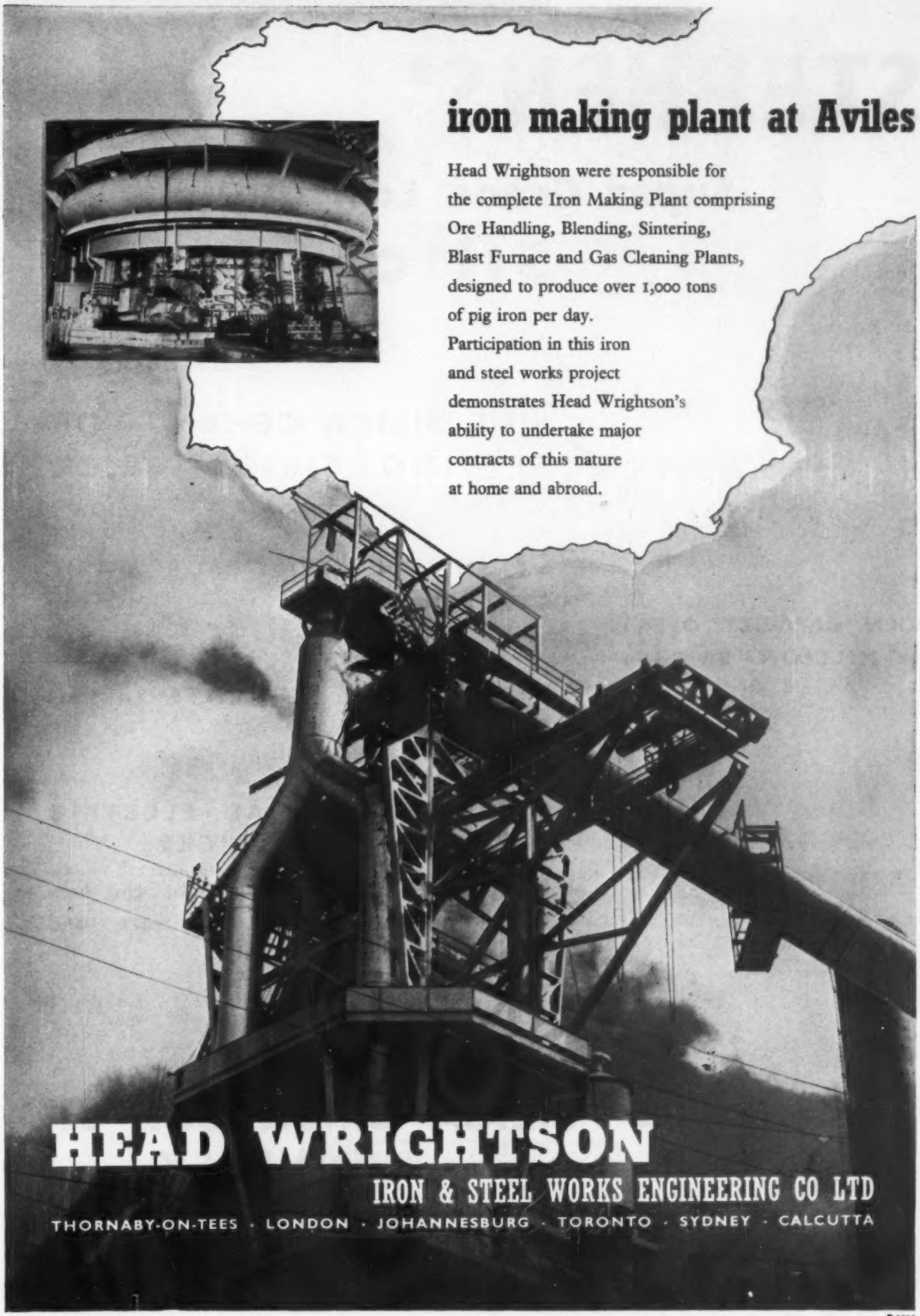
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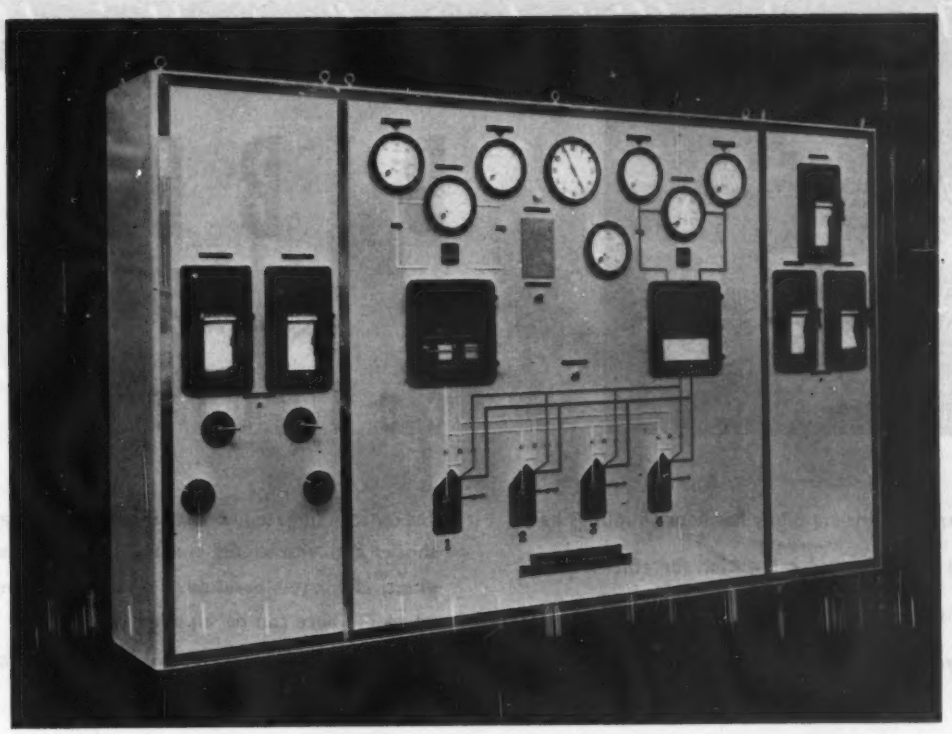

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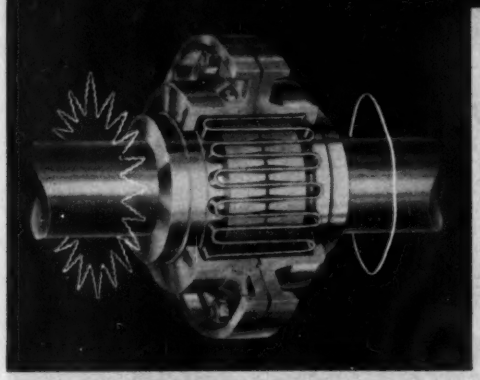

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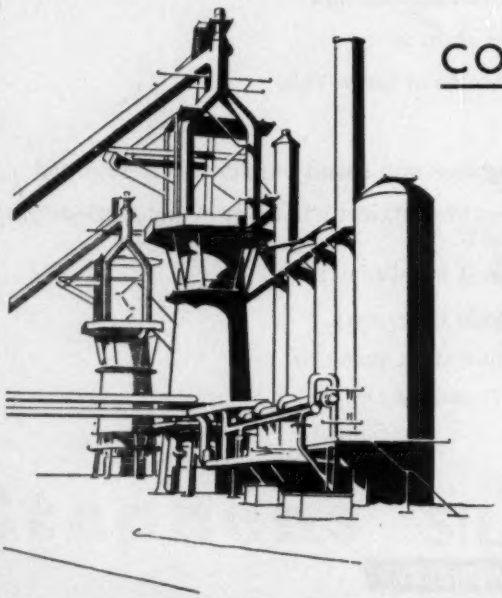

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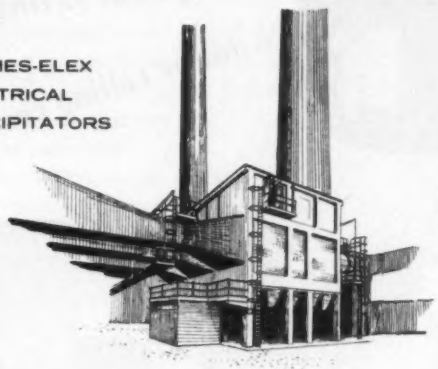

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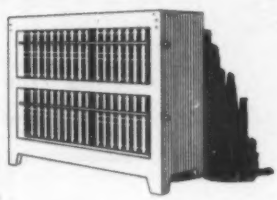

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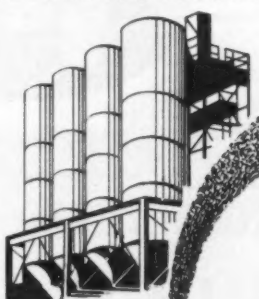

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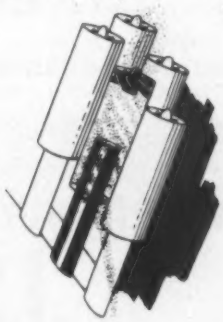

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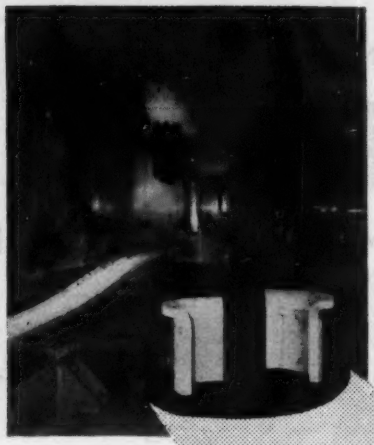

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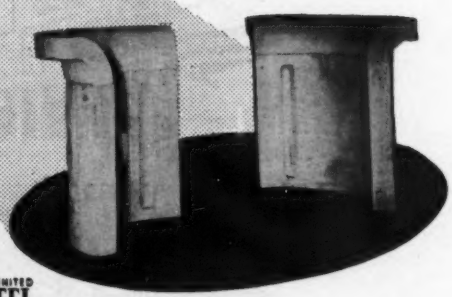

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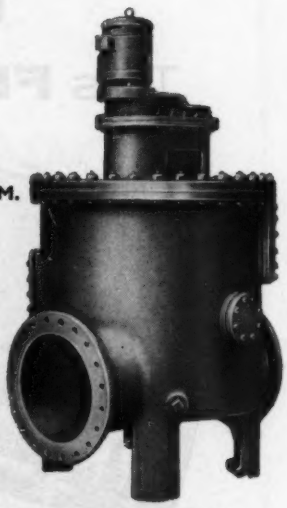

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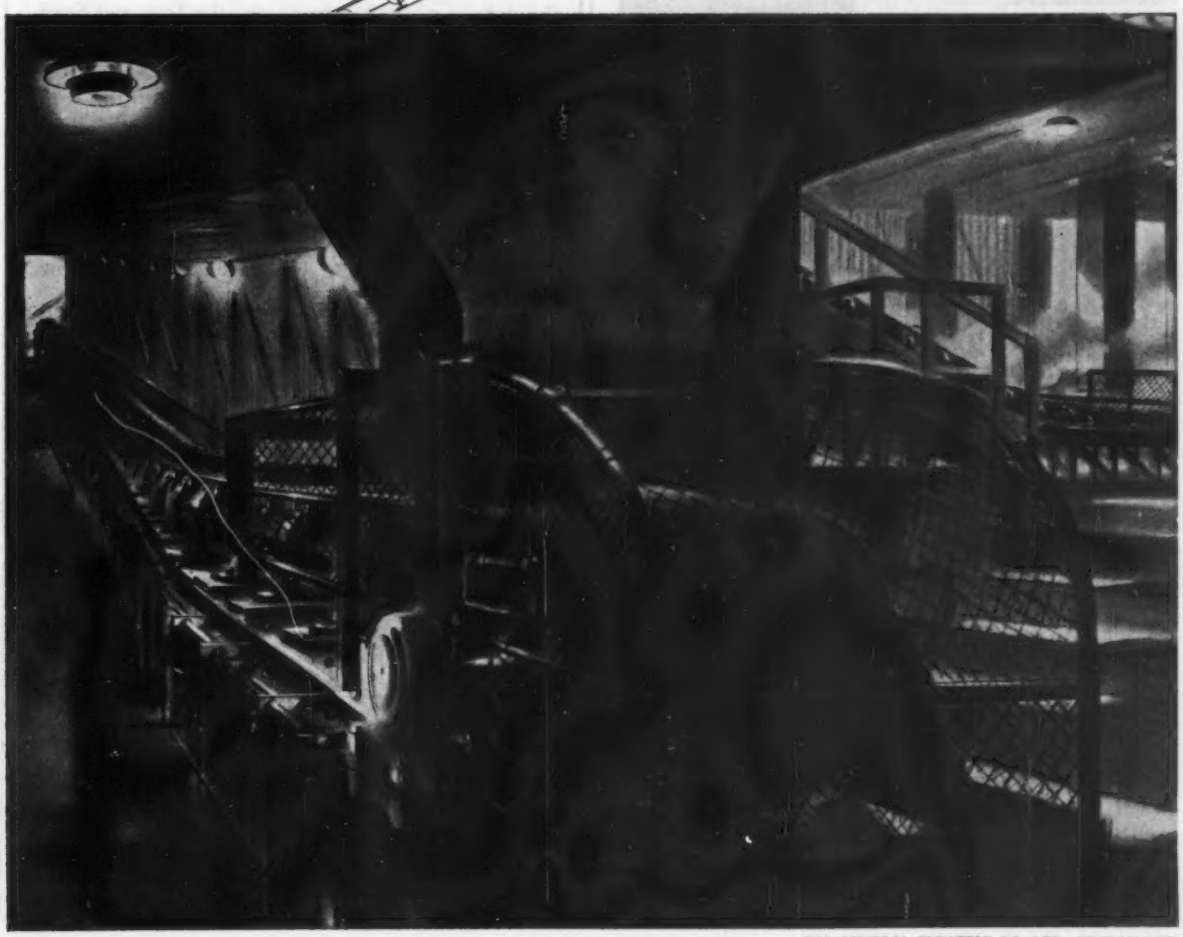

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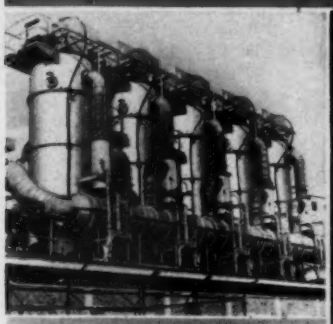

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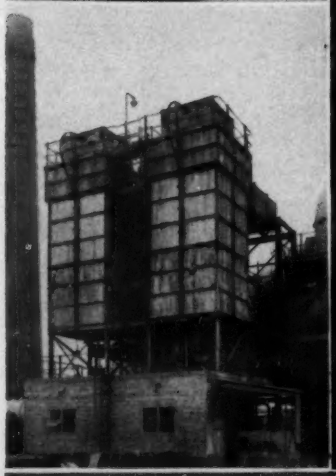

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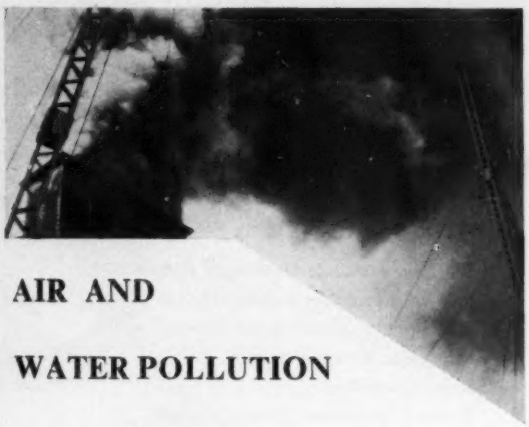

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Twenty-five papers were written especially for the meetings, by authors from Austria, France, Germany, the U.S.A., and the U.K. During the meetings some lively and informative discussions took place, in which experts in a variety of fields gave their views. The papers, reports of the discussions, and contributions received subsequently to the meetings, together with additional authors' replies, have now been published as a Special Report in one volume of 260 pp.

The report, No. 61 in the Special Report series of the Institute, is illustrated with over 200 diagrams and photographs and is bound in cloth with stiff board covers. Copies can be obtained from the offices of the Institute, 4, Grosvenor Gardens, London, S.W.1, price £4 5s. 0d. (Members £4 5s. 0d.)

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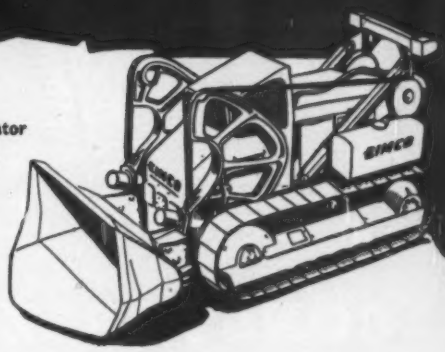

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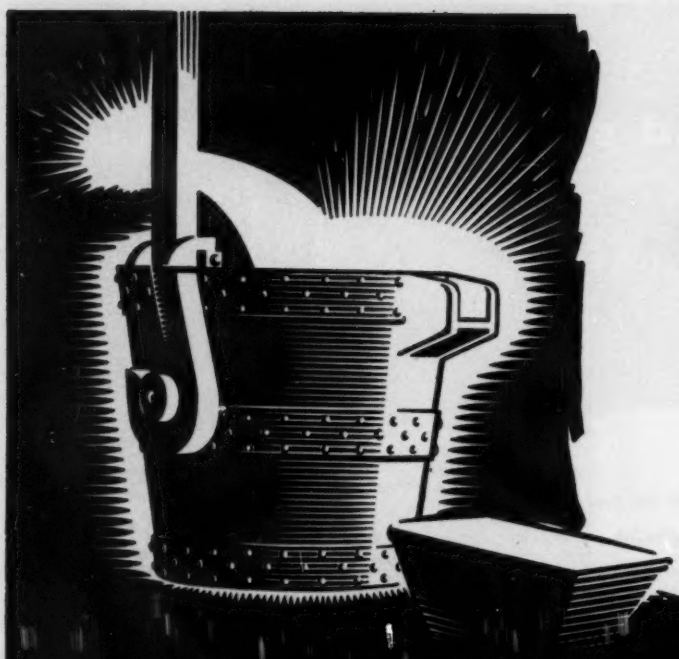

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THE IRON AND STEEL INSTITUTE

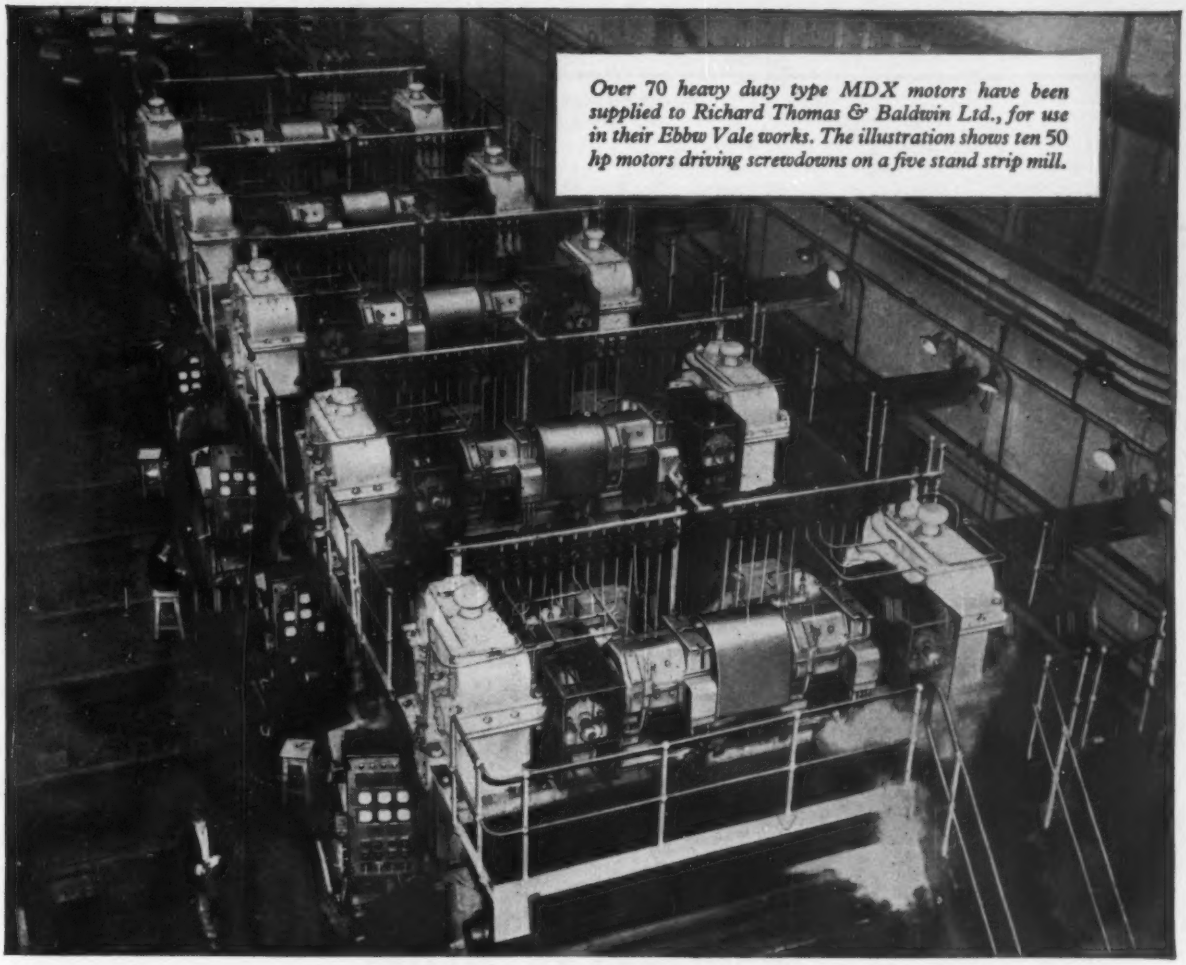
Special Report No. 60

Proceedings of the

FORGEMASTERS' MEETING, 1954

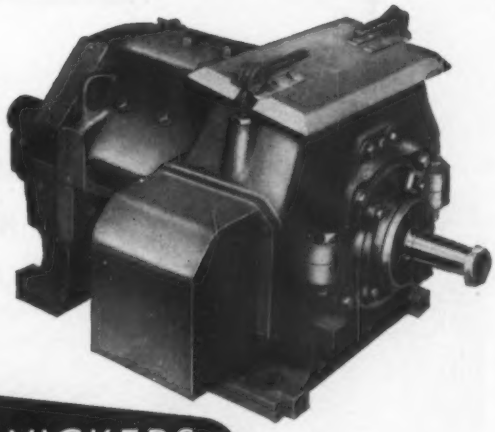
In October, 1954, The Iron and Steel Institute held a Joint Meeting with the National Forgemasters' Association and La Chambre Syndicale de la Grosse Forge Française. Technical Sessions were held in London at which nine papers on forging theory and practice and forging plant were presented and discussed. The remainder of the Meeting comprised visits to the English Steel Corporation Ltd., Thos. Firth and John Brown Ltd., and Hadfield Ltd., in Sheffield.

The Proceedings at the Technical Sessions have been published as a Special Report. The five French papers and discussion are presented in English, but summaries of all the papers are also given in French. The Report, No. 60 in the Special Report series of the Institute, can be obtained from the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, price 37*s.* 6*d.* (Members 25*s.*).



Over 70 heavy duty type MDX motors have been supplied to Richard Thomas & Baldwin Ltd., for use in their Ebbw Vale works. The illustration shows ten 50 hp motors driving screwdowns on a five stand strip mill.

All motors here are type MDX



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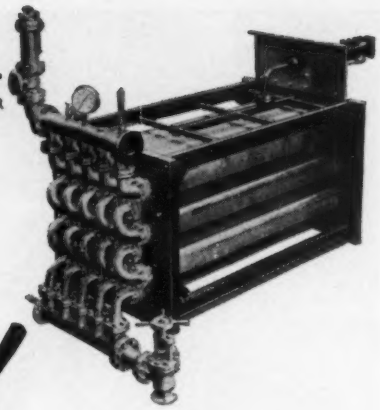

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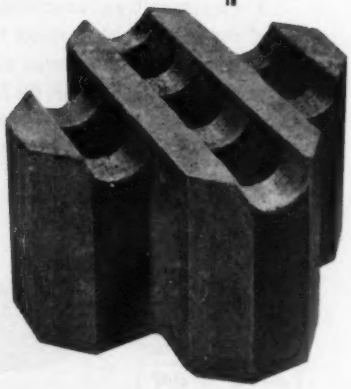

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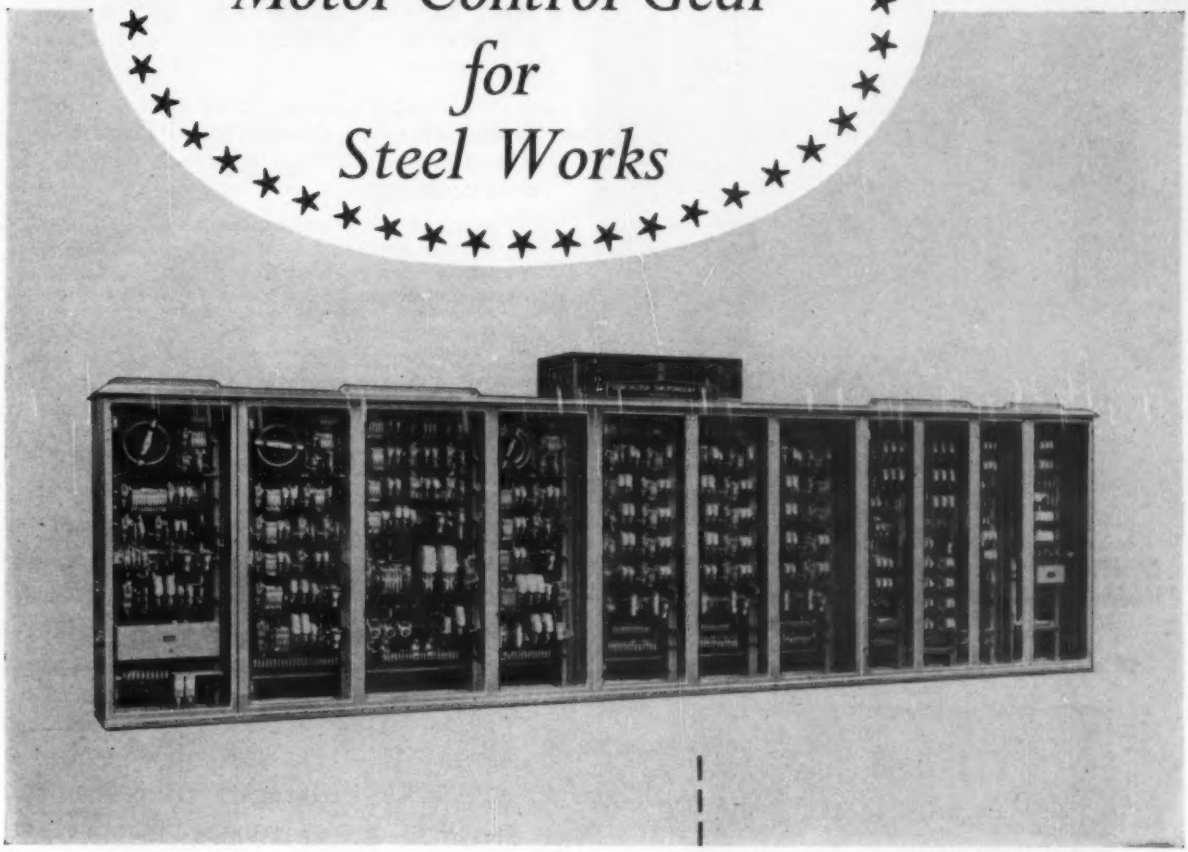

This rolling mill auxiliaries panel was designed with two compartments for constant speed A.C. and variable speed D.C. motors respectively, and supplied together with two control desks.

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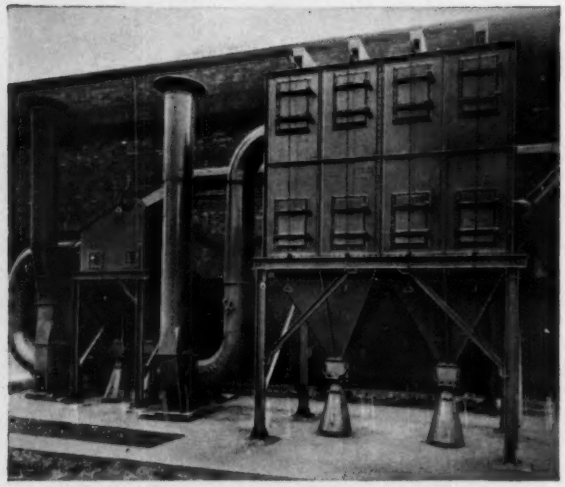

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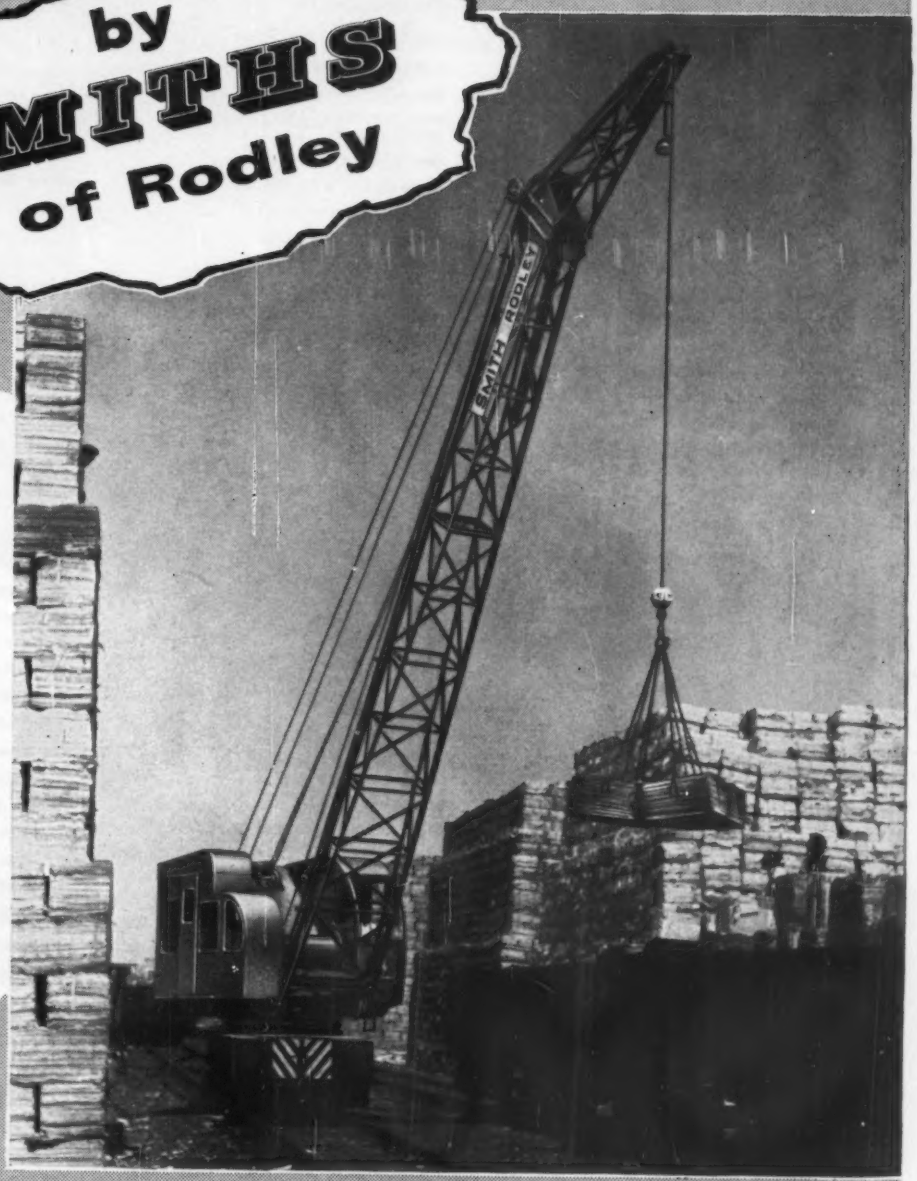

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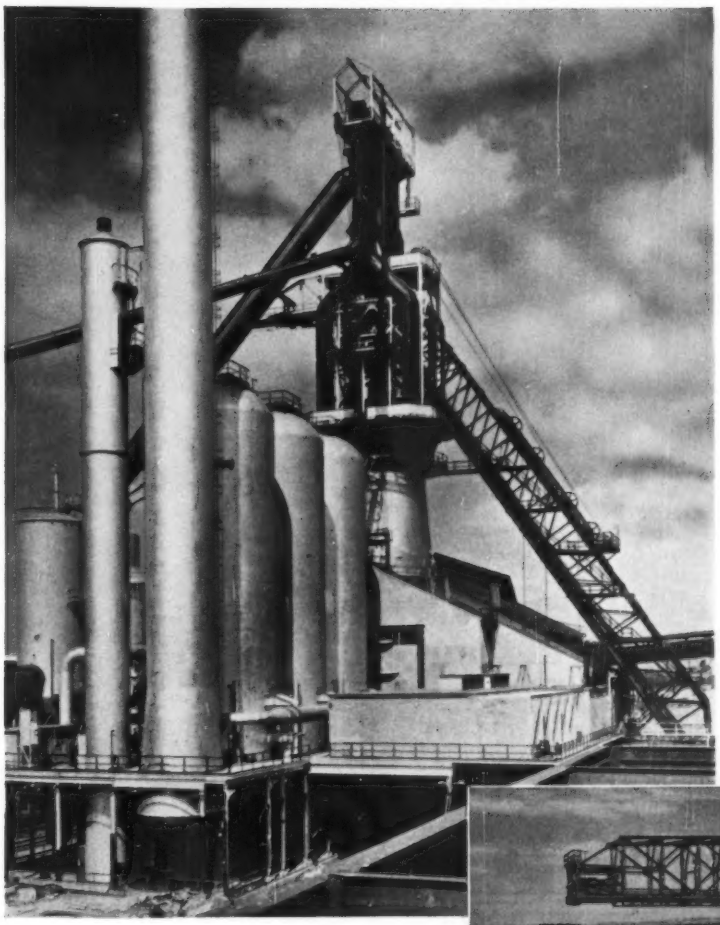

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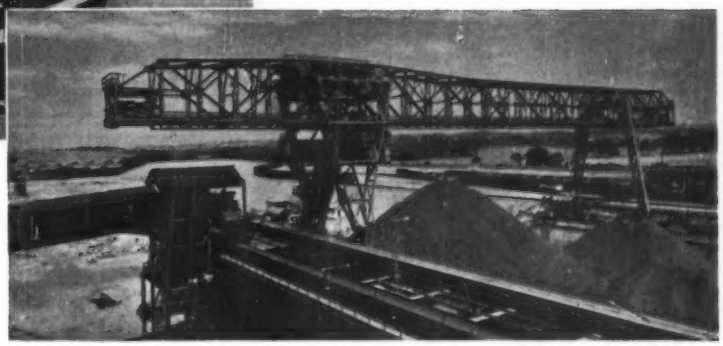

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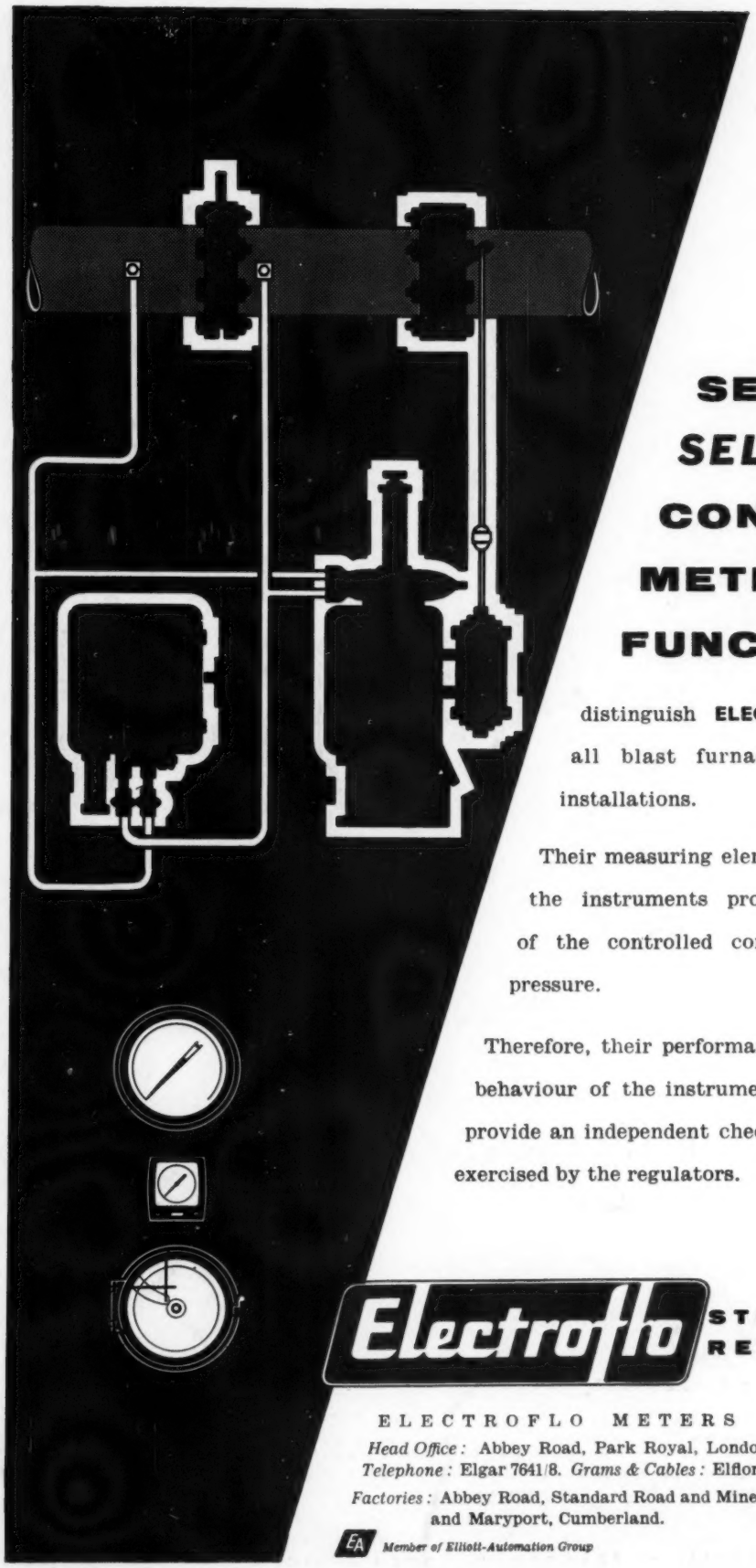

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